UNIVERSITY OF TORONTO
3 1761 01183389 4

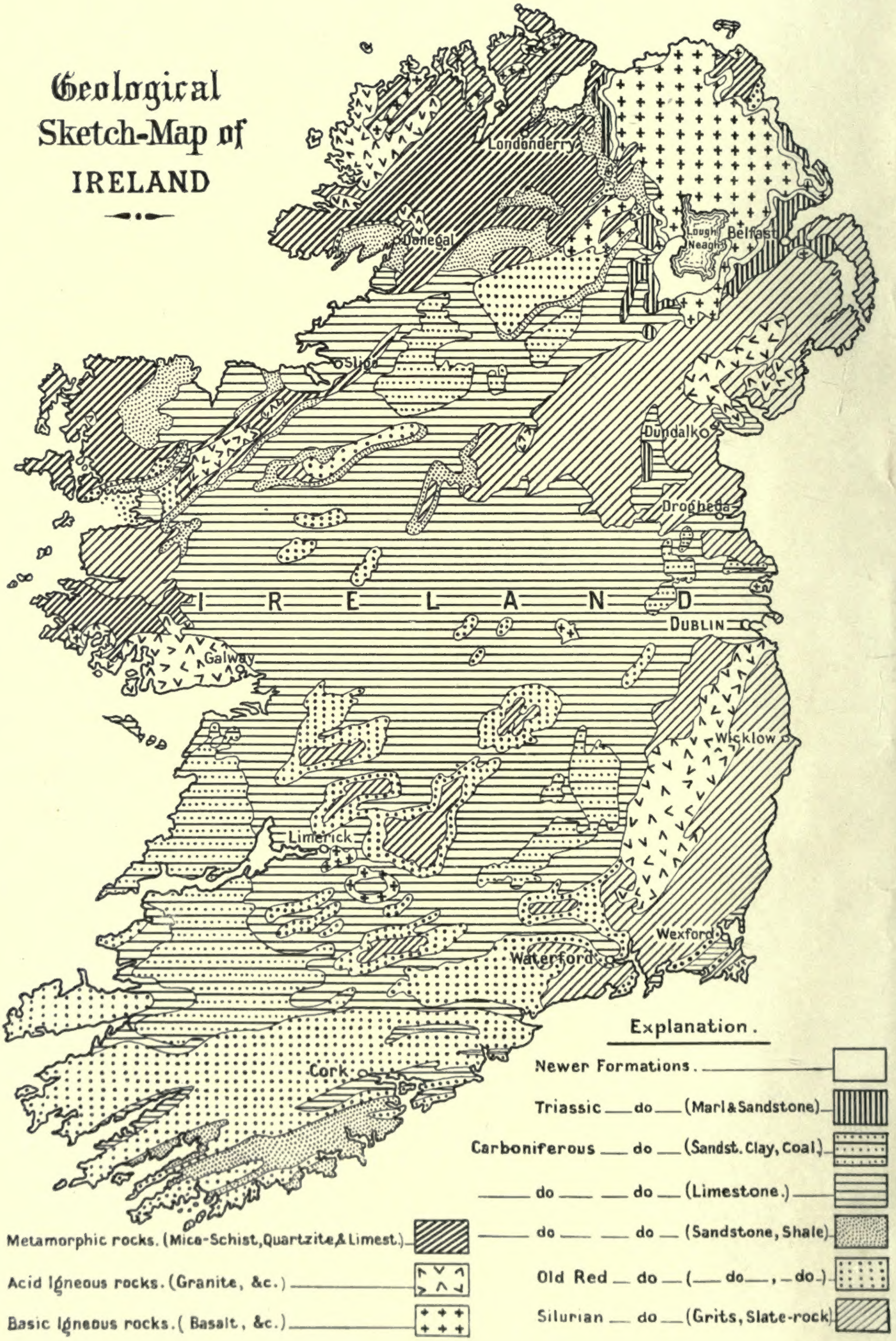
GIFT
MAR 1977

Augustus Englebrecht
1956

Digitized by the Internet Archive
in 2008 with funding from
Microsoft Corporation

http://www.archive.org/details/descriptionofsoi00kilruoft

Geological Sketch-Map of IRELAND


Londonderry
Donegal
Lough Neagh
Belfast
Sligo
Dundalk
Drogheda
IRELAND
DUBLIN
Galway
Wicklow
Limerick
Wexford
Waterford
Cork
Explanation.
Newer Formations.
Triassic do (Marl & Sandstone)
Carboniferous do (Sandst. Clay, Coal)
do do (Limestone.)
do do (Sandstone, Shale)
Old Red do (do, do.)
Silurian do (Grits, Slate-rock)
Metamorphic rocks. (Mica-Schist, Quartzite & Limest.)
Acid Igneous rocks. (Granite, &c.)
Basic Igneous rocks. (Basalt, &c.)

DEPARTMENT OF AGRICULTURE AND TECHNICAL
INSTRUCTION FOR IRELAND.

A DESCRIPTION OF THE

SOIL-GEOLOGY OF IRELAND,

BASED UPON GEOLOGICAL SURVEY MAPS
AND RECORDS,

WITH

NOTES ON CLIMATE,

BY

J. R KILROE.

DUBLIN:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
BY ALEX. THOM & CO., LIMITED, 87, 88, & 89, ABBEY-STREET.

And to be purchased, either directly or through any Bookseller, from
E. PONSONBY, 116, GRAFTON-STREET, DUBLIN; or
WYMAN & SONS, LTD., FETTER-LANE, E.C., or
OLIVER & BOYD, EDINBURGH.

1907.
Price Six Shillings.

QE
265
K5

LIBRARY
SEP
25
1970
SITY
OF TORONTO

PREFATORY NOTES.

The Geological Survey of the United Kingdom was instituted in January, 1845, and its work commenced in May of that year. In Ireland, the southern counties first received attention, and the results of the operations carried on by the Irish branch of the Survey originally appeared on small-scale county maps. These maps were afterwards replaced by sheets on the scale of one inch to the mile, accompanied by Explanatory Memoirs—each sheet representing twelve miles by eighteen. The issue of the series of one-inch maps now obtainable commenced in 1857 and was completed in 1890, when the ordinary field-work of the Survey terminated. From 1890 to 1901 a small staff was retained for the purpose of bringing the published maps into conformity with recent geological work elsewhere, especially in Great Britain, the rapid progress of the science having rendered this necessary, in the case of the earlier survey-work.

The examination of soils and subsoils formed an important part of the regular work of the Survey, for several years at the outset; and collections of samples were made throughout many of the townlands of Cork, Waterford, and Kilkenny. The exigencies of purely scientific research, however, and the demand for a greater rate of progress in the mapping, necessitated an abandonment of soil and subsoil examination, which was not resumed prior to 1901.

The one-inch geological map of Ireland having been completed, the opportunity seemed favourable for presenting to the public a succinct account of the geology of the country, prepared chiefly from the standpoint of agriculture. My proposal to do this was approved of by my late chief, Sir Archibald Geikie, who, although the work should necessarily be ultra-official, sanctioned for the purpose the use of illustrations drawn from official sources, and free access to all official maps and records. The present work was undertaken in 1897, and the extent of my indebtedness to many authorities and friends is apparent throughout the text. To one who—no longer with us—held a leading place amongst English scientific and experimental agriculturists, I am especially indebted. To another—a director of the Agricultural department of an English college—I owe the suggestion that an account of Irish climate should form an important feature of the work.

The manuscript of the book was handed over by Sir A. Geikie in 1901, to the Department of Agriculture. Since then Mr. Primrose M'Connell's book on Agricultural Geology, King's Physics of Agriculture, Hall's Text-book of the Soil, and other kindred works have appeared, as well as the Department's elaborate book, "Ireland, Industrial and Agricultural"; the more important points treated of in these works, in so far as they bear upon the subject in hand, have induced and enabled me to render more complete certain portions of the work.

A small geological sketch-map of Ireland, representing the structure of the solid crust in this area, forms the Frontispiece, and will be found useful for general reference. Together with this, according to the original intention of Sir A. Geikie, the volume is accompanied by a map on the scale of ten miles to an inch, showing in elaborate detail the areas covered with drifts, bog, and water, as well as the solid strata and igneous masses, where the rock is to be seen. It has been prepared from the one-inch published Survey maps, and embodies most of the recent revision work, in so far as this was completed up to the year 1900. This includes results which appear on amended issues of the one-inch maps, and some results not hitherto presented to the public in map form, though described in the Annual Summaries of Progress of the Geological Survey, 1893–97.

Regarding the revision-work in the West of Ireland, attention may especially be called to alterations it was found necessary to make in the mapping of the Silurian tract. This is now known to extend all the way northward from the Killaries to Clew Bay, Croagh Patrick range being formed of highly altered Wenlock strata.

The granitic gneisses of Erris (North Mayo), of the Ox Mountains, Connemara, and South Donegal, which, on account of lithological similarity to those of the North-west of Scotland, were supposed to be of Archæan age, are now known to be intrusive rocks, newer than the adjoining mica-schists, quartzites and limestones, and are represented accordingly.

Other less important differences have also been duly noted upon the present map, with a view to bringing this into line with information obtained up to 1900.

It remains for me to explain that, having in view a class of readers more conversant, perhaps, with the industrial aspects of the subjects than the scientific, I have avoided, as much as possible, geological expressions which might be thought too technical, and have distinguished by capital initials, and otherwise, some which were unavoidable. To facilitate reference, paragraph headings and other means have abundantly been used.

James R. Kilroe.

ERRATUM.

Last line but one (page 103) read "been" for "being."

[*To face page* [5.]

SOIL-GEOLOGY OF IRELAND, WITH NOTES ON CLIMATE.

Contents.

SECTION I.

Chapter I.—General Remarks.

Relation of soil to sub-soil—Soils of different origins—Moory soils—Peat ashes—Alluvial soils—Slob lands—Foreshores—Shell gravels—Coralline sand—Sand tracts—Seaweed—Clay soils—Functions of worms in the soil—Soil waste and replenishment—Mouldering rock—Rain-wash and wind-drift—Soil endowment—*Lime*—*Magnesia*—*Potash*—*Phosphoric acid*—Functions of mineral substances—Nitric acid—Available plant-food—Micro-organisms.

CHAPTER II.

Rocks and their Lithological Characters.

Classification of rocks—*Aqueous rocks*—Clay and slate group—Sandstone—Building stone—Rock-salt, gypsum, &c.—Limestone—Peat, lignite, coal—*Igneous rocks*—Rock-forming minerals—Volcanic and Plutonic Rocks—Acid group—Granite—Felsite—Basic group—Diorite—Basalt. Page 19.

CHAPTER III.

Superficial Deposits.

Agricultural and Geological Maps—Transplacements of rock-detritus—Area covered with Drifts—Means of judging soils—Elements of enrichment—Deterioration—Table of soils and sub-soils.
Page 33.

SECTION II.

The Geological Formations from an Agricultural Point of View.

CHAPTER IV.

Nature and Order of Formations.

The term Formation explained—Stratification—Table of Formations—Marine denudation—Disturbance and crumpling of strata—Geological sections—Peculiarities attaching to the rocks of each Formation—Granite not always the most ancient rock of a region.
Page 42.

CHAPTER V.

METAMORPHIC ROCKS.

Main group of Metamorphic rocks—Gneiss and Mica schist—Areas formed of these rocks in Ireland—Characteristics of soils formed therefrom—Analyses of Metamorphic rocks—Hornblende schists—Limestone and marble—Soils they form—Quartzite—Conical and "sugar-loaf" hills—Scenery. Page 54.

CHAPTER VI.

CAMBRIAN AND SILURIAN.

Area occupied by rocks of these Formations—Distribution in Ireland, gritty and slaty in general character—Calcareous throughout wide areas in the east, centre, and south of Ireland—Soils derived from Silurian rocks—Silurian soils of France—Slate-rock—Scenery of these Formations—Facilities for irrigation. Page 64.

CHAPTER VII.

OLD RED SANDSTONE.

Present and original distribution of Old Red Sandstone strata—Lower and Upper Divisions—Thicknesses of the Formation in various places—Oldest land-plants—Munster and Ulster—Scenic features—Soils derived from the rocks of Formation—Irrigation—Water "hardness." Page 71.

CHAPTER VIII.

CARBONIFEROUS SYSTEM.

Limestone a source of fertility to nearly one-half of the country—Scarcity of Coal—Original extension of the Formation—A three-fold division—*Lower Carboniferous Sandstone, and Shale*—Soils derived from these strata—Analyses of some clays and sandstones—Rocks of South-west Cork—*Middle series*—Extent of limestone—Argillaceous and arenaceous limestone—Hydraulic lime—"Calp" or Middle Limestone—Soils yielded by "Calp"—Phosphates supplied by limestone—Analyses of limestones—Drain upon the phosphates in soils—Composition of slaughtered animals—Soxhlet's experiments—Irrigation—Great accumulation of limestone *débris*—How accounted for—Probable great plain of marine denudation—Central Plain—Scenery in various limestone regions—*Upper series*—Resemblance to Lower Series—Unfavourably situated for agriculture—Quantity of coal in Ireland—Fire-clay.
Page 80.

CHAPTER IX.

Newer Formations.

Nearly all found in North-east Ulster—Permian, chiefly conglomerates and dolomites—Triassic System—*New Red sandstone* and *New Red marl*—Chiefly in the country bordering Belfast Lough—Lower Series, sandstone—Upper Series, marl, with salt and gypsum—Analyses by Grandeau—Jurassic System, Lias—Contains dark limestone—Cretaceous System—Greensand—Chalk or white limestone—Tertiary Group—Basalt—Associated iron-ore and leaf-beds—Lough Neagh clays—Economic Minerals. Page 105.

CHAPTER X.

Igneous Rocks.

Acid Group—Principal granite areas—Mourne granite—Older granites of North Mayo and Wexford—Donegal and Galway granites—Granite-disintegration—Granite soils—Granite regions of France—Irrigation—Felsites of Mayo, North Galway and Wexford — Felsites associated with Old Red Sandstone strata, and with Antrim basalts—Analyses of some Acid Igneous rocks—Basic Group—Hornblende schist associated with other Metamorphic rocks—Basalt in Carboniferous rocks—Basalt in the North-east of Ireland—Large dykes in Fermanagh and Donegal—Soils formed from basalt—Top-dressing with detritus of Basic rocks—Table of Analyses—Irrigation. Page 114.

CHAPTER XI.

Drift.

Glacial conditions in Ireland—Erratics—Means of their transport—Glacial phenomena in Switzerland—Glacial striæ in Ireland—Two prevailing sets of striæ in Ulster—Boulder-clays—*Lower Boulder-clay* or Till—Limestone gravels and Boulder-clay—*Middle sands and gravels*—*Upper Boulder-clay*—Means of its transport and deposition—Its character as a soil-forming material—*Eskers*—Origin of Eskers—*Moraines.* Page 130.

CHAPTER XII.

Peat and Alluvium.

Peat-formation—Former great extension of lakes and marshes—Aggregate peat area—Rate of growth—Bog timber—Chief peat-forming plants—Johnson on the Irish Peat Question—Shrinkage of peat in drying—Its heating power—Compressed peat—Economic products—Bog iron-ore—Bog Springs and Bog-flows—Methods of draining—Alluvium —Drainage areas in relation to fertility—Arterial and thorough drainage schemes—Afforestation—Trees for peaty lands—The Pine weevil—Expenses and Profits. Page 150.

CHAPTER XIII.

WATER SUPPLY.

Drainage areas and Watersheds—Supplies for towns—Dublin and Belfast supplies—Permeable strata—Artesian wells—Springs—A specific case—Wells in New Red Sandstone—Lisdoonvarna and Lucan waters—Springs in Drifts—Water-hardness—Water-power. Page 175.

CHAPTER XIV.

RECENT LIFE FORMS.

Animal remains in peat—Cave deposits—Local nomenclature—Spontaneous migration—Opinion of Zoologists—Mingling of forms—A view of migration and of conditions in the Glacial Period—Physicist's objections. Page 189.

SECTION III.

THE DRIFTS OF IRELAND AND THEIR RELATION TO THE SOILS OF THE FOUR PROVINCES.

CHAPTER XV.

ULSTER.

Distinctive characters of Drift in different districts—Detailed information arranged accordingly—Modification of soils of the province by Glacial circumstances.

DISTRICT 1.—West Donegal, region lying to the west of a line passing southward from Lough Swilly to Bundoran by Lough Erne—Thick deposits of boulder-clays in valleys—*Moraines*—Economic clays.

DISTRICT 2.—Parts of Donegal Londonderry, and Tyrone, eastward as far as Limavady, and southward to the latitude of Lower Lough Erne—Drift rising to 1,300 feet on the Sperin Mountains—Different characters of boulder-clay—Sands and gravels—*Eskers*—Economic clays.

DISTRICT 3.—Antrim, Down, Armagh, and parts of Londonderry, Tyrone, and Louth, East of the meridian through Limavady, and extending southward to Dundalk Bay—Varieties of rocks contained in the Antrim Drift—Vestiges of Boulder-clay up to 1,100 feet on Slievc Gullion—Stratified sands and gravels—*Eskers*—Economic clays.

DISTRICT 4.—Cavan and parts of Tyrone and Monaghan—Extending southward from District 2 to the boundary of the province—Drifts partaking of the nature of the underlying rocks—Sands and gravels—Economic clays. Page 198.

CHAPTER XVI.

CONNAUGHT.

Modifications of the soils of the Province by Glacial circumstances.

DISTRICT 1.—Counties of Leitrim and Sligo, and the portion of Roscommon lying to the north of Boyle—Drift at elevations of 400 to 800 feet skirting the Ox Mountains—Sometimes met with at 1,500 eet—Accumulations of sand and gravel—*Eskers*—Economic clays.

DISTRICT 2.—North Mayo, lying to the west of District 1, and north of Clew Bay—*Lower Boulder-clay*, 40 to 50 feet deep in Erris —Sandy *Upper Boulder-clay*—*Eskers*—Economic clays.

DISTRICT 3.—South Mayo and West Galway, stretching between Clew Bay and the Aran Islands, and lying to the west of Lough Mask and Lough Corrib—Stratified Drift—Limestone Till—Boulder-clay in Aran—Sand and gravel—*Eskers*—Economic clays.

DISTRICT 4.—South-east Mayo, East Galway, and Roscommon, extending from Districts 1, 2, and 3 to the Province boundary—Large "drumlins" near Castlebar—*Lower* and *Upper Boulder-clays*—Stony Drift—*Eskers*—Economic clays. Page 211.

CHAPTER XVII.

LEINSTER.

Modifications of soils of the Province by Glacial circumstances.

DISTRICT 1.—Louth and North-east Meath, extending southward to Balbriggan and westward to Kells—Variety of stones in the Drift—Sands and gravels—*Eskers*—Economic clays.

DISTRICT 2.—Bounded on the north by District 1 and Ulster; extending southward to the latitude of Parsonstown, and the boundary of Wicklow; and lying between the Shannon and the Irish Sea —Large area of Limestone Drift—Gravel found at 1,235 feet elevation at Kilmashogue—*Eskers*—Three main chains—The Curragh—Economic clays.

DISTRICT 3.—Including the portion of Leinster lying to the east of a meridian through central Carlow, and south of District 2. Limestone gravels—Granite detritus about Lough Bray—*Upper Boulder-clay*—Sections of Drift along the Wexford Coast—"Manure Gravels"—Remarkable assemblage of granite blocks—Brick clay.

DISTRICT 4.—South-western portion of Leinster, lying to the south of District 2 and west of District 3—Drift reaches 1,300 feet elevation in Glenbarrow on Slieve Bloom—Limestone Drift on the Coal Measure hills—*Lower and Upper Boulder-clays*—Peat beneath 96 feet of Drift—*Eskers*—Pipe-clay and brick-clay. Page 219.

CHAPTER XVIII.

MUNSTER.

Modifications of soils of the Province by Glacial circumstances.

DISTRICT 1.—North-western Munster, extending southward to Dingle Bay, Castleisland, and Newmarket; and eastward to the meridian, through Ennis—Drift chiefly derived from local strata—Contains fragments of limestone and granite—Limestone blocks in Finglas Valley used for making lime—*Moraines*—Glaciation up to 1,300 feet—Economic clays.

DISTRICT 2.—North-eastern Munster, extending westward to District 1, and southward to a line passing through Doneraile and Carrick-on-Suir—Limestone Drift amongst the Silurian hills of the Keeper group—Also over the Coal Measure ground near Charleville —*Eskers, sands, &c.*—Economic clays.

DISTRICT 3.—Southern Munster, extending northward as far as the boundaries of Districts 1 and 2—Locally formed Drift reaching an elevation of 2,050 feet in the Bochragh range—Limestone Drift at Bantry—Stratified sands and gravels at Cork—*Moraines.*

Page 232.

SECTION V.

CLIMATE.

CHAPTER XIX.

INFLUENCE OF THE IRISH CLIMATE ON AGRICULTURE.

Unfavourable characteristics of the Irish climate—Removal of forests—Effects of vegetation—Seasonal modifications—Influence upon stock and tillage—Climate and weather—DISTRIBUTION OF TEMPERATURE—Internal heat—Latitude—The Gulf Stream—Configuration—Aspect—Relation of temperatures of soil and air—Schübler's and Wollny's Researches—Effects of rolling soils—AERIAL CURRENTS—Cyclonic winds—Courses of cyclones—*Atmospheric moisture—Condensation—Wet and dry winds*—Clouds—*Rainfall—Weather Prognostication*—Applications of Meteorology—Concluding remarks—Meteorological tables—Note on Evaporation from trees—Note on relative humidity. Page 240.

APPENDIX.

Modern Soil-research—France—Germany—America—Belgium—England—Geological Survey—Rothamsted—Sampling soils and subsoils—Mechanical Analysis. Page 279.

LIST OF ILLUSTRATIONS

Page

Frontispiece.

No. 1. Sketch at High Cross, ... 10

,, 2. Section seen in Railway cutting,... 11

,, 3. Section in quarry, ... 11

,, 4. Effects of inoculating soil, ... 18

Tailpiece. Old Sea stack and Cliffs near Castle Robin, ... 32

No. 5. The Cliffs of Moher, ... 44

,, 6. Section through Knocknashee, showing succession of Carboniferous Rocks, ... 45

,, 7. Diagr. Sketch of Cleavage in Limestone, ... 46

,, 8. Contorted limestone beds, ... 47

,, 9. Bull's Head, showing Old Red Sandstone on Dingle beds, .. 48

,, 10. Old Red Sandstone resting on Silurian slates and grits, ... 48

,, 11. Section across Galtymore, ... 49

,, 12. Plan of portion of Pigeon Rock Mountain, ... 51

,, 13. Section across Barnavave Mountain, ... 52

Tailpiece. Cave, north end of Cruit, Donegal, ... 53

No. 14. View of Errigal, ... 60

,, 15. Doon Rock, ... 61

,, 16. Muckish Mountain, ... 62

Tailpiece. Glenbeagh, looking S.W., ... 63

No. 17. The Devil's Bit, from the north, ... 69

,, 18. The Devil's Bit, from the south, ... 69

,, 19. Section through hill near Roxborough, ... 72

,, 20. Old Red Sandstone tree-fern, ... 73

,, 21. View of Mangerton Range, ... 75

,, 22. View of the Reeks from the ridge west of Gap of Dunloe, ... 76

Tailpiece. Valencia Island, ... 79

No. 23. } ,, 24. } Sections across Slieve Bloom,... 82

,, 25. Section across Old Red Sandstone Ridge, ... 86

,, 26. Section across part of Cork, ... 86

,, 27. Chert in Upper Limestone, Co. Cork, ... 87

,, 28. View of Linestone Plain, ... 97

,, 29. Horizontal Sections in North Leitrim and Sligo, ... 100

,, 30. Benbulben, from Finisklin, ... 101

,, 31. Terraced Limestone of Burren District, Co. Clare, ... 102

Tailpiece. "Cloghvorra," a limestone boulder in Kenmare Valley, ... 104

Page
No. 32. Section in Limestone Quarry, Co. Down,... 106
„ 33. Carnmoney Hill, Co. Antrim, ... 106
Tailpiece. Columnar Basalt over Pisolitic Iron Ore, ... 113
No. 34. The Mountains of Mourne, ... 115
„ 35. Coast Cliffs near the Giant's Causeway, ... 122
„ 36. Horizontal Section across Hills near Cushendall, ... 124
„ 37. Dyke penetrating limestone and basalt, ... 125
Tailpiece. Slemish Mountain, ... 129
No. 38. Granite erratic blocks on a hill near Luggala, ... 130
„ 39. Cloughlowrish Stone, ... 131
„ 40. Butterlump Rock, ... 132
„ 41. Block of gray limestone near Clonmacnoise, ... 132
„ 42. Perched Boulder near Dunmanway, ... 133
„ 43. Rock rounded by glaciation at Loo Bridge, ... 135
„ 44. Dinin River, Co. Kilkenny, ... 138
„ 45. Section at Coonbeg, Queen's County, ... 139
„ 46. Drift section near Eshbane, ... 139
„ 47. View of Esker, from Rahugh, Westmeath, ... 145
„ 48. Ballyduff and Newtownlow Esker, ... 146
„ 49. Plan of Eskers near Streamstown, ... 147
„ 50. Waterworn blocks of limestone, ... 152
Nos. 51-55. Sections illustrating relations between pervious and impervious strata 180
Nos. 56-59. Sections showing relations of sands, boulder-clay, talus, and underlying rock, ... 185
Tailpiece. Sugarloaf Rock near Waterford, ... 188
No. 60. Post Pliocene Deposits, Glenulra River, ... 214
„ 61. Drift at Ballinskelligs Bay, ... 236
„ 62. Illustration of differences in sun's heating power caused by aspect, ... 248
„ 63. Map of Cyclone showing course of depression-centre, ... 257
„ 64. Part of storeroom for samples, Rothamsted, ... 283
„ 65. „ „ Central Hall, Rothamsted, ... 283
„ 66. Earth-boring implements, ... 286

SOIL-GEOLOGY OF IRELAND

WITH NOTES ON CLIMATE.

SECTION I.

CHAPTER I.—GENERAL REMARKS.

SOIL AND SUBSOIL.

The term *soil* is here applied to signify the more or less incoherent superficial earth-covering, from which crops, including pasture, are raised. In this signification of the term it denotes not only the substances in which clay forms a chief component, and which are frequently distinguished as clay-soils, but other accumulations of different origins, to be mentioned presently. It is also necessary to note the distinction which subsists between *soil* and *subsoil*—between the uppermost layer which is usually dealt with in cultivation, and the deeper material upon which it rests. The soil, where clay is abundant in both it and the subsoil, possesses greater looseness of texture, and is usually of a darker colour, owing to the presence of decaying organic matter (chiefly carbonaceous, but also nitrogenous), which ordinarily represents, in cultivated land, incorporated farmyard manure and crop residues. Soils may vary in depth from a few inches to over a foot, and graduate almost imperceptibly downward into the subsoil. The mineral components of both are often in the main very similar, and show that the difference in character is superinduced by cultivation and weathering. Soil and subsoil are also distinguishable in moors and alluvial deposits, the differences being attributable to natural and artificial causes similar to those above indicated.

VARIETIES OF SOIL-FORMING MATERIALS.

The numerous varieties of soils commonly met with, originate in natural processes, which have operated on a large scale, and for ages, in moulding and modifying the present surface of the country. Reference to them is, therefore, made in the following classification, commencing with those most recently formed:—

Moory Soils.—These chiefly consist of peat or bog, that is, vegetable matter in various stages of decay. They may be deemed entitled to be called soils only when brought under cultivation: it has been estimated that somewhere about 1,500,000 acres of peat throughout the country are capable of reclamation.

Peat Ashes.

Even the purest varieties of peat when burnt leave small quantities of ash. This residue represents the mineral substances embodied in the fabric of the once living vegetable-matter, and remains after the carbon, oxygen, hydrogen and nitrogen—the organic elements of the plants—have been driven off in the process of combustion. These mineral substances were drawn from the clay underlying the bog by means of the water, which supplied moisture to the growing plants. Doubtless dust falling upon the bog surface from the atmosphere also contributes a small proportion of ash—in part, as supplying constituents to the peat-forming plants, and partly as extraneous material. The quantity of ash may also be increased by substances in solution and sediments carried by underground waters, which well up occasionally as voluminous springs, to permeate the peat in certain bogs, as will be mentioned in a subsequent chapter. Flood-waters also charged with clay, sand, and even gravel, may overflow bogs on sloping ground, during the progress of their growth, which accounts for thin layers of these materials occasionally to be met with in turf-cutting.

Composition of Ashes.

As may be expected, chemical analyses of peat present a great variety, in regard of composition, as well as quantity of ashes. Some contain a considerable proportion of iron oxide, as may be judged from their strong red colour. Potash is present in small quantities in every ash specimen. Analyses of Irish peat ashes,* by Kane, Sullivan, and Gages, show considerable percentages of phosphoric acid† and lime.

The following analyses of peat ashes, selected from a series of twenty-seven made by Sir R. Kane, are collated from works on Metallurgy.‡ Attention may be directed to the great variation noticeable in the proportionate quantities of the chief components.

*Recorded in Watt's Chemical Dictionary and books on Metallurgy, mentioned on pages 157, 158.

†The quantities of phosphoric acid in these peat ashes is the more remarkable seeing that, as noted by Sir R. Kane in his "Industrial Resources," Boussingault never could detect it in turf ashes.

‡ Phillips' "Metallurgy" (p. 37 ; ed. 1887), and Percy's (p. 209 ; ed. 1875).

[TABLE.

TABLE OF ANALYSES.

Component.	Riversdale Bog, near Kinnegad.	Athlone Bog.	Curragh Bogs, near Shannon Bridge.	Phillipstown Bogs.		Wood of Allen.	
				1.	2.	1.	2.
Potash, . . .	0·641	0·744	1·667	1·323	0·461	0·491	0·247
Soda, . . .	1·875	0·704	2·823	1·902	1·399	1·670	0·496
Lime, . . .	22·702	40·623	20·907	36·496	40·920	33·037	24·944
Magnesia, . .	6·809	4·352	5·252	7·634	1·611	7·523	1·285
Alumina, . .	1·109	1·671	2·034	5·411	3·993	1·686	0·360
Iron Oxide, . .	29 854	10·368	17·040	15·608	15·969	13·281	19·405
Phosphoric Acid, .	2·019	1·114	1·447	2·571	1·406	1·438	·242
Sulphuric Acid, .	16 381	24·208	23·375	14·092	14·507	20·076	10·742
HydrochloricAcid,	1·591	1·052	1·424	1·482	·983	1·747	·335
Silica, . . . (Soluble in acids.)	0·737	6·317	6·634	3·595	1·111	2·148	1·082
Sand, . . . (Insoluble silica and silicates.)	14·505	3·710	10·682	2·168	2·107	7·683	26·789
Carbonic Acid, .	1·470	4·981	6·721	7·761	15·040	8·340	13·890
Totals, . .	99·693	99·844	100·006	100·043	99·309	99·120	99·817

Alluvial Soils.—These are to be found along the margins of streams and rivers, forming flats or callows; or in drained tracts where the streams have well nigh disappeared. They are mainly formed of sediments carried down from the higher grounds and deposited on land temporarily covered with water. Alternate growths of grass, rushes, reeds, &c., on the flood plains, increase materially the thickness of the deposits; and the organic matter resulting from the decay of such plants, enhances the quality as well as adding to the quantity of alluvial matter. The removal of obstruction in a watercourse by natural or artificial means, may so lower the level of the water, as to lay bare callows or "bottoms," which may afterwards have their surfaces gradually raised, owing to the deposit of sediments by subsequent floods and by growth of vegetation.

Sections of alluvial deposits, seen along the banks of the tortuous channels traversing them, show stratified assortments of clay, sand, and gravel, the relative coarseness of the materials varying with the rapidity of the current that transported them. These mineral forms of detritus are often marked by admixtures or interstratifications of peat, representing successive vegetable surfaces on the flood plains, when the water flowed off moory tracts. In some cases alluvium consists almost wholly of peaty matter, and may dovetail at its margin with the peat of an adjoining bog.

Brick Earth.

Brick-earth may accumulate as an alluvial deposit. The results of this process may be seen in many places throughout the extensive flats which border Lough Erne on either side. A valuable brick-earth, rich in diatomacean remains, occurs along the valley of the Bann. It was formed when the waters of Lough Neagh extended northward beyond Toome. Reference will be made in a subsequent chapter to extensive drainage works which have been carried out in Ireland. It will there also be shown what alterations of level have taken place within recent times in the great water arteries of the country.

Deltas.

From what has been stated it will be perceived that alluvial soils may comprise a great variety of materials. Alluvial soils form the deltas at the mouths of many streams and rivers, when the sediments carried along by running water settle down on reaching the still waters of lakes, inland seas, and oceans. The deposit thus formed, sooner or later reaches near enough to the surface to allow of the growth of reeds and other water plants, which, by their accumulation, and the way in which they arrest the silt, contribute to the formation of alluvial tracts above the water level, which can be cultivated. Illustrations are to be found in green callows which stretch into lakes, and through which sluggish streams wend their way towards the gradually receding water beyond. Examples of such deposits in Ireland are to be seen where the Bann enters Lough Beg in Antrim; at Portumna, where the Shannon enters Lough Derg; and, as a less important instance, where the Avonmore enters the well-known lake, Lough Tay, in Wicklow.

Slob-lands, Fore-shores, Raised Beaches, &c.—Alluvial sediments carried down by streams and spread out over shallow estuaries, or mingling with sands and seaweed drifted by currents, and accumulated in sheltered portions of the coast, may ultimately be heightened by the growth of terrestrial vegetation, the accumulation of animal remains, possibly also the drifting of dust and other causes—until the water of high tides no longer covers the deposit. In such circumstances it has frequently been found profitable in this country and elsewhere, especially in the case of land-locked bays, to construct embankments for the purpose of excluding tidal waters and discharging the drainage from the land through self-acting sluices at ebb-tide. Were a slight elevation of the land to take place, it would relieve wide stretches of foreshore of all, or nearly all, water, thus rendering them amenable to cultivation. Such an elevation is known to have occurred along the north coast of Ireland, resulting in raised beaches,* to be seen at many points; just as a depression of the land within recent times is proved by the existence of bogs *below low-water mark* at various points along the west coast.* The comparatively recent elevation of land along the north coast has given rise to the extensive cultivated tract at the entrance to Lough Foyle, near Newtownlimavady.

---

* Mr. Kinahan speaks of two Raised Beaches indicating stages of elevation 25 and 12 feet above present High Water mark: the first seems to be older than some peat growths; the latter is doubtful. "Geology of Ireland," by G. H. Kinahan, M.R.I.A., p. 264. See Report on Raised Beaches of N.E. Ireland by R. Lloyd Praeger, B.A., Proc. Roy. I. Acad., vol. iv., series 3 (1891), p. 30-54; also Chapter XIV., present volume.

Shell Gravels and Coralline Sand.

Soils along the coast-line may, through the accumulation of seaweeds and shells, be very rich in fertilizing substances. In the harbours of Kinsale, Cork, and Youghal, calcareous sands are also obtained for manuring. These consist of minute whole shells, and particles of finely-broken larger shells, mingled with fragmentary crustacean remains, which are rich in phosphates.† Coralline sand is also dredged in quantities for manure in Bantry Bay.

Coralline sand, a marine product of vegetable origin, rich in calcareous matter, occurs at Ballyconneely and Mannin Bays, on the Galway coast. Samples from Knockboy, on the Galway coast, and from Bantry have been analysed by Mr. R. J. Moss, F.C.S., F.I.C., and the results, published in a paper by Prof. T. Johnson and Miss Hensman, read before the Royal Dublin Society,‡ are here given.

RESULTS OF ANALYSIS OF "CORALLINE SAND."

—	Knockboy.	Bantry.
Moisture,	0·70	1·38
Iron and Aluminum Oxides,	·55	·94
Lime,	33·26	44·63
Magnesia,	·28	3·40
Soda,	1·53	·92
Potash,	1·54	·36
Silica,	—	·23
Carbonic Acid,	28·65	37·50
Phosphoric Acid,	Trace.	·06
Sulphuric Acid,	Trace.	·61
Chlorine,	0·18	·76
Organic and Volatile§ Matter by difference,	4·49	5·50
Sand, insoluble matter,	28·82	3·71
	100·00	100·00

---

* Explanation of Geological Survey Sheets 1 to 6, p. iii., and of Sheet 83, p. 69. Mr. Kinahan, in his "Geology of Ireland" (pp. 264, 265), gives the following instances, viz. :—At Aran Islands, Galway Bay; Dunworly Bay, South Coast of Cork, where the bog was found to be more than 50 feet in depth; Clonea, near Dungarvan, and Tramore, Co. Waterford.

† "Industrial Resources of Ireland," 1844, p. 273.

‡ A List of Irish Corallinaceæ by T. Johnson, D.SC. Lond., F.L.S., and Miss Hensman, Sci. Proc., Roy. Dub. Soc. Vol. ix., N.S., 1899, p. 24.

§ Containing nitrogen 0·056, 0·073 per cent.

The substance, omitting extraneous matter, is chiefly a secretion product of *Lithothamnion coralloïdes*, belonging to the sub-order *Corallinaceæ*, and consists almost wholly of carbonate of lime. It is widely distributed and, as a mixture containing fragments of shells and sand, forms a deposit which is known in the maritime parts of Brittany (France) as "mail."

Sand Tracts.—Strong winds blowing over sandy beaches temporarily free of tidal water and dry, carry the finer sand above the shore line. This has taken place at many points of the Irish coast. The resulting accumulations, which are in some cases of considerable depth, have, around the whole coast of Ireland, an aggregate area of about 38,400 acres.* In parts the surface of these "blown sands" is moderately level or gently undulating, and covered with scanty herbage, which prevents further shifting. When the sand is affected by wind, it is liable to collect in *dunes* or hillocks, and ridges, in which case it serves as rabbit-warrens. Reckless removal of the natural herbage of those sand-wastes has often led to widespread devastation by the blown sand. The conservation of the important sand tract at Myroe or Magilligan in North Londonderry, for example, is due to the successful growth of the Little Sea Bent-grass (*Agrostis maritima*).† "Bent," which binds the sand together, should in the first instance be planted, and allowed to establish itself, cultivation being delayed until the sand can be prevented moving before the wind. In the beginning of the last century Rutland, off the coast of Donegal, was a green, prosperous island, with a military station, and according to Lord George Hill, in his book, "Hints to Donegal Tourists"—"quite a gay place." To-day it is a sand waste, the former habitations being almost completely covered.‡ At Doonera, on the Sligo coast, the sand travelled in recent times so as to cover up the church of Ballintemple, and the hamlet to the level of the chimney-tops.§

Occasionally, where the sand consists largely of comminuted marine shells and other organisms, or where land snails abound, the loose material is cemented together by the action of rain in dissolving the lime from the organic remains, and re-depositing it among the particles as the moisture evaporates. Loose sand may thus be consolidated into a compact stone, sufficiently durable to be capable of being employed as a building material, as near New Quay, in Cornwall.

---

* As estimated by Messrs. Kinahan and M'Henry, in "A Handy Book on the Reclamation of Waste Lands in Ireland," p. 35.

† See Sampson's "Statistical Account of Londonderry," p. 451.

‡ Explanatory memoir of Sheet 15, Geol. Survey of Ireland.

§ Explanatory memoir of Sheets 42, 43.

Seaweed is an important component of some littoral soils, the value of which may in part be judged from the composition of its principal varieties.* Besides containing a large proportion of mineral constituents, it shows a fair proportion of nitrogen, 100 parts of dried weed containing, according to Way, 65 · 62 parts of organic matter, 13 · 65 soda, 16 · 00 soluble salts, and 3 · 23 nitrogen (=4 parts ammonia). *Laminaria digitata*, "black tangle," has only about 1 · 4 per cent. of nitrogen when dry, while *Porphyra lancinata*, "laver," has as much as 4 · 65 per cent.

On account of convenience of transport, the ash of sea-weed (kelp or varec), which is chiefly prepared as a source of iodine and potassium salts, is often used as manure. A few samples showing the proportions of mineral constituents in the ash of the principal weeds are here given:—

ANALYSES OF SEAWEED ASHES.

Constituents of the Ashes.	*Laminaria saccharina* (North Sea.)	*Laminaria latifolia* (Hoffsmansgave.)	*Fucus digitatus* (Clyde mouth.)	*Fucus nodosus* (Clyde mouth.)	*Fucus serratus* (Clyde mouth.)
Potash, ...	24·77	16·91	22·40	10·07	4·51
Soda, ...	1·84	—	8·29	15·80	21·15
Lime, ...	6·50	8·28	8·79	10·98	11·09
Magnesia, ...	8·13	6·80	7·44	10·93	11·66
Sodic chloride, ...	33·72	26·92	28·39	20·16	18·76
Potass, ,, ...	—	10·18	—	—	—
Sodic Iodide, ...	4·70	—	3·62	0·54	1·33
Calcic Phosphate,	8·41	12·80	5·63	3·34	9·67
Ferric ,, ...	0·75	—	—	—	—
,, Oxide, ...	—	—	0·62	0·29	0.34
Sulphuric Acid, ...	10·60	12·63	13·26	26·69	21·06
Silica, ...	0·58	0·69	1·56	1·20	0·43
	100·00	95·21	100·00	100·00	100·00
Percentage of Ash in weed dried at 100°C.	17·8 ?	13·62	20·40	16·19	15·63
Authorities, ...	Schwitzer.	Forchammer	Godecheus.		

Clay Soils.—Soil in the sense in which the term is most generally understood, consists of a mixture of clay and sand, with gravel sometimes, in various proportions. It occasionally forms only a thin layer between the surface and the solid rock underneath, but more usually it rests upon subsoil of greater or less thickness. This subsoil consists under ordinary conditions of the upper disintegrated or decayed layer of the rock or stone below; and so varies in colour according to locality and other circumstances. It may be dark gray, or black, owing to the presence of carbonaceous matter. If specimens of such subsoil be burned, the dark colour disappears through the combustion of the carbon: the burnt residue will then probably be dull white, or gray, the colour proper to soils. It may also be yellow, red, or brown, owing to the presence of iron oxide in various proportions. Such earths become bleached through the oxidation of the carbonaceous matter or the dissolving out of the iron by naturally acidulated rain and drainage waters. The differences noticeable in this class of soils, both as regards the characters they assume—often little more than an admixture of sand and gravel—their mode of occurrence, and the manner of their formation, form the principal portion of our theme in this book.

Functions of Worms, &c.

The necessity, under ordinary circumstances, of maintaining a soil in an open permeable condition, admitting of the free percolation of rain-water and access of atmospheric air to the interstices is very obvious; and towards this end nature co-operates with man. Not only do decaying roots and rootlets leave channels along which descending waters may course, but worms and burrowing animals subserve similar ends. Worms, moreover, perform an additional service. The ejection of so-called "worm casts" is familiar to all. By this means finely divided and enriching materials are brought up from below and distributed over the surface. Nor is the quantity of such ejections insignificant. Darwin estimated that 53,000 worms per acre inhabit garden soil; that ten tons per acre of soil pass through their bodies annually, while they feed upon the organic matter which the ground contains; and that three inches of soil in depth would be brought to the surface by these workers in fifteen years.* In 1771 Gilbert White wrote:—"Worms seem great promoters of vegetation, which would proceed but lamely without them, by boring, perforating, and loosening the soil, and rendering it pervious to rains and fibres of plants; by drawing straws and stalks of leaves into it; and most of all by throwing up such infinite numbers of lumps of earth called worm casts, which, being their excrements, is a fine manure for grain and grass." The mingling of soil components thus proceeds: worms rarely inhabit peaty soils, but ants, beetles, &c., perform functions here, similar to those which worms fulfil in clay soils.

Soil Waste.

Waste of the soil incessantly goes on in greater or less degree. During wind or heavy rains the process may be witnessed by any observer; the fact is further attested by the quantities of mud carried towards the sea by every rivulet, stream, and river, in flood times; and shallow soil upon rock is soon cleared away except when under grass; but even then waste proceeds. Nor is the amount of waste to be measured by the mud visibly held in suspension in flood waters. Mr. T. Mellard Reade estimated that 8,370,630 tons of solids in solution are transferred to the ocean from the surface of England and Wales every year.[*] Similar waste proceeds in Ireland according to its area, and is of a character which affects the agricultural interest even more than the loss of sediments visible in river-water at flood times; for the material carried off in solution, contains a much larger percentage of fertilizing substances than the sediments represent.

---

* Thompson's "Study of Animal Life." 2nd ed. , pp. 22, 23.

Rock Solubility.

Rock masses and detached stones and particles undergo solution by weak acids entering and passing through the soil. To illustrate this fact, and test the solubility of limestone as compared with that of granite, experiments were made[†], in the Geological Survey Laboratory, upon fragments which would pass through a 3-16 in. mesh. These were placed in glass tubes of ¾-inch internal diameter, through which a stream of water, acidulated with carbonic acid, was allowed to trickle at the rate of 1 litre per hour, for 55 hours, spread over a period of nine weeks. Coralline sand was also tested in this manner, and the results were found to be as follows:—

TABLE SHOWING LOSS BY SOLUTION OF GRANITE, LIMESTONE, AND CORALLINE SAND.

Material in Small Fragments.	Weight in Grammes.	Loss in Grammes.	Loss per cent.
Granite, ...	82·386	·011	·013
Limestone, ...	70·856	2·258	3·187
Coralline Sand, ...	47·001	4·555	9·691

Soil Replenishment.

This waste would obviously tell upon the country were it not that the soil is replenished. It receives accession of materials from two sources—from the atmosphere, and from the subsoil, or from the solid crust. In the former case rain-water, particularly near towns and manufacturing centres, carries down certain quantities of chlorides and sulphates of soda, potash, lime, and magnesia; nitrates, and nitrites of ammonia; particles of organic matter, and germs of vegetable and animal matter, all of which substances are beneficial to vegetation. Dew and hoar frost condensed from the lower stratum of the atmosphere are also rich in these substances. Dust wafted hither and thither by winds rests and accumulates in sheltered spots, which it thus enriches at the expense of other places. The principal accession of materials is from the solid crust—not now mentioning the transformation of subsoils into soils. Rain-water charged with carbonic and other acids in filtering through the soils, having oxygen also dissolved in it, penetrates every joint and crevice of the crust, oxidizing, dissolving, and disintegrating the solid rock. Roots of plants render powerful aid; recurring frosts also expand the already formed joints and fissures, and, forming others, leave the mass still more open to attack by the other agencies. In digging through the soil to the crust beneath in certain places, one may frequently observe a distinct gradation from finely pulverized material at the surface, to rubble, which rests immediately upon the disintegrating rock beneath. This is exhibited in the accompanying illustrations.* Figure 1 is a sketch taken at High Cross, near Donaghy, Co. Tyrone, which represents beds of limestone breaking up as they approach the surface. Limestone is seldom, if ever, devoid of extraneous matter—clay and sand; and often contains layers of shale between its beds. When the carbonate of lime (limestone) dissolves away the earthy substances remain as soil and subsoil.

---

[*] "Text-book of Geology." Sir A. Geikie, LL.D., D.C.L., F.R.S., 1st ed. p. 339.

[†] By the writer.

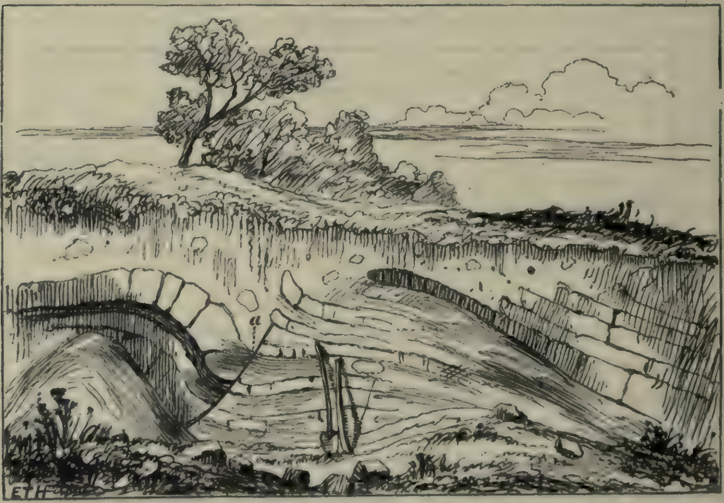
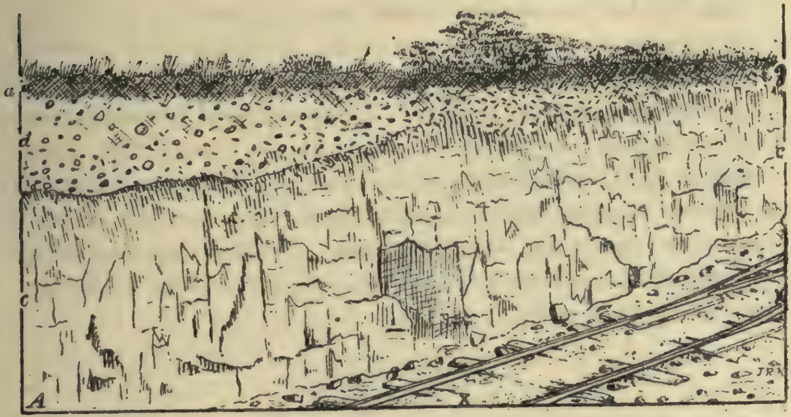


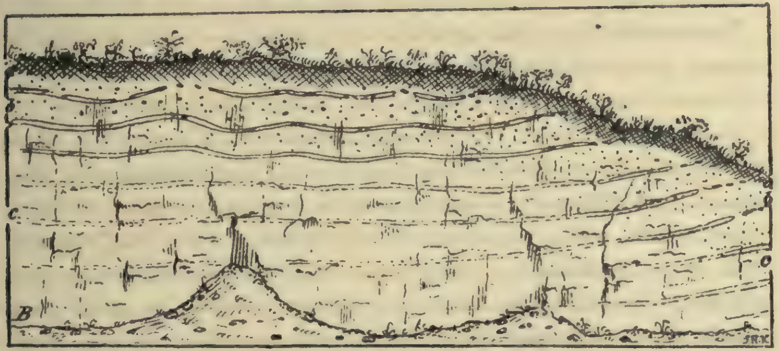
Fig. 1. Sketch at High Cross, near Donaghy, showing limestone undergoing disintegration.

Figures 2 and 3 represent the formation of subsoil from weathering

* Fig. 1 is taken from Explanation of Sheet 35, p. 33.

slate and basalt, respectively. The former also shows the incoming of *Drift* soil and subsoil, with stones not derived from slate.





A. (Fig. 2.) Section seen in Railway cutting through slate-rock (New Ross and Waterford Extension, near New Ross.) Sketch from photograph, by the writer, showing—Soil (*a*); subsoil, detritus of slate (*b*); slate-rock (*c*); Drift under soil (*d*); ×, temporary railway.

B. (Fig. 3.) Section in quarry; Mullaghglass, near Collin Hill, Antrim; showing basalt weathering to some three feet from surface. Soil 9in. deep (*a*); subsoil, distintegrated rock (*b*); (*c*), solid basalt traversed by thin layers somewhat more compact than containing rock, and remaining intact in disintegrated portions.

Mouldering Rock.

Along the high banks of streams, the rock there exposed may retain the form of a solid mass, yet may have been so corroded internally by the decomposing action of infiltering moisture, that a walking-stick can sometimes be thrust several inches, or to a greater depth, into the mouldering material. It is by this process of gradual disintegration and decay that subsoils have been formed, out of which upland or clay soils have been produced.

The nature of the material resulting from the decompositions, above described, will obviously depend upon that of the original rock.

Rain Wash and Wind Drift.

Near the bottom of steep slopes, the soils frequently represent a mixture of components formed partly by disintegrated rock or Drift materials below, and partly by rain-wash from the hills—with beneficial physical results. The down-wash frequently contains fertilizing ingredients not found in the low ground, which therefore adds enrichment to the latter. Wind, too, operates powerfully upon steep slopes, carrying upward particles of clay, sand, rock, dust, and small fragments, detached by alternating heat and frost from the solid masses, and distributing them upon the level surface above.

Soil Endowment.

The weathering, disintegration and partial solution of rocks, in nature, produces soils endowed to a greater or less degree, with substances which minister to growth in vegetation, and which will now be mentioned. Of the four substances of geological origin which seem to be the most important in soils—phosphoric acid, lime, potash, and magnesia—some soils have a preponderance of one or more, which does not render them necessarily fertile. They may lack or be deficient in one or more of the other important components; a necessary condition to fertility, therefore, is an adequate supply of all that are essential; and this can best, perhaps alone, be naturally afforded by a mingling of soil materials derived from different sources. The means by which the condition has been brought about to a very large extent in Ireland, will be presented in a future chapter. Here it is necessary to consider the manner in which the leading substances occur in the soil—nitrogen excepted.

Lime.—This substance ranks as one of the most important. It is not only a leading element of plant food, but serves salutary chemical and physical ends; it neutralises the acidity of soils and is an ameliorative, where it is applied. A small percentage of lime, sufficient to meet the nutritive requirements of vegetation, is not therefore a true index of the amount requisite. Lime occurs in soils in the forms of carbonates, sulphate, compound silicates, and phosphates, all of which, though inappreciably soluble in water, dissolve with different degrees of rapidity in waters charged with carbonic, and weak nitric and organic acids. The effectiveness of lime as a fertilizer depends largely upon the ease with which the particular compound of it in a soil, yields to solvents.

Magnesia is a usual accompaniment of lime, and is an important soil ingredient. It is now recognised that most soils are already sufficiently furnished with this substance, in such forms as carbonates and silicates.

Potash.—Few earths are devoid of this component. Heavy clay soils, and those derived from granites and potash-felsites, are usually richly endowed with it. Carbonate of potash, a product of decomposition of rock, and of finely-divided felspathic mud, may be present in soils; and even nitrate and sulphate of potash of like origin, may also occur. The commonest compounds of potash, which are extremely stable, are complex silicates, and these are with difficulty soluble even in weak acids. For this reason, there may be but a small supply immediately available for plant food, though analyses may reveal a large percentage in the clays.

Regarding potash, M. Risler writes:—"..... the glacial clays of the Rhone Valley ....contain from 0·118 to 0·164 per cent. of soluble (*attaquable*) potash, and 0·054 to 0·07 per cent. of phosphoric acid."*

Phosphoric Acid (Phosphoric anhydride plus water).—The quantity of this substance in plant ashes, and its presence in protoplasm, are suggestive of its importance. The necessity for it, as a bone-forming substance in herbivorous animals, also renders phosphorus an important element to the agriculturist. It is exceedingly rare to find soils rich in this element; between ·1 and ·2 per cent., it is stated, would be a high average. Russian "Black Earth" gives the unusual quantity of ·6 per cent.†

Sir R. Kane, in his "Industrial Resources," mentioned the possibility of natural supplies in Irish soils becoming exhausted; and the great drain in this respect upon the store-feeding and barley-growing lands might in some measure justify the apprehension. In fattening lands there is, of course, not the same drain upon this substance. Phosphoric acid in soils, occurs chiefly in combination with lime and iron, and the ordinarily occurring compounds are but slightly soluble. A still less soluble phosphate of iron is found in ill-drained land, in which case the phosphoric acid is practically worthless for crops. The supply of phosphates in the limestone land of this country will be referred to later on.

---

* Given on the authority of M. de Gasparin, *Géologie Agricole, Tome* I., p. 9: de Gasparin's solvent was *aqua regia.*

† Johnston's "Elements of Agricultural Chemistry," by Cameron and Aikman, p. 147.

Functions of Mineral Substances.

A highly-important Paper* dealing with the characteristic functions and effects of the various substances named above, has been issued by the Rothamsted authorities, and has so obvious a bearing on the main branch of the agricultural industry in Ireland, that apology need scarcely be offered for giving here some of the more important conclusions arrived at.

First, with respect to the functions attaching to the several substances, Adolph Mayer's conclusions are adopted, and summarized somewhat as follows (p. 152).

Phosphorus (received in phosphates) plays an important part in the production of proteids.

Chlorine, though not apparently an essential ash-constituent, contributes visibly to the prosperity of buckwheat and other crops. It also seems to aid the solution of starch grains and favour the circulation of starch in plants.

Potassium plays the corresponding role in the formation of carbohydrates to that which phosphorus does in the case of proteids. The so-called "potash plants" are those in which large amounts of carbohydrates (starch, cellulose, sugar, &c.), are produced.

Calcium salts seem to take part in the transport of starch (formed, we may add, in the foliage, and stored up in roots, tubers, &c.), and the conversion of organic substance into "building material." It is chiefly found in the leaves.

Magnesium seems to follow the proteids through the plant.

Iron is necessary for the formation of chlorophyll.

Amongst the many points which received demonstration is the important one that the botanical nature, manifest character or appearance, and *composition* of herbage, and in consequence its feeding capabilities, are dependent upon the plant food available in soils; thus, nitrogenous compounds tended greatly to increase the weight and comparative number of gramineous species at the expense of the leguminous species; whilst mixed mineral manures, including potash, had the contrary effect: and only when mixed mineral and nitrogenous manures are used together are the best crops produced. Again, stemminess and maturing tendencies attach to abundant potash supplies (pp. 181 and 182), while leafiness attaches to the prevalence of lime and soda. The latter mineral, and even lime to a certain extent, may replace potash, in plants, where supplies of potash in the soil are deficient; but always with their characteristic effects upon vegetation, so that the substances are not strictly interchangeable.

---

* "Agricultural, Botanical, and Chemical Results of Experiments on the Mixed Herbage of Permanent Grass Lands," by Sir John Bennet Lawes, Bart., D.C.L., D.SC., F.R.S., and Sir Joseph Henry Gilbert, LL.D., D.SC., F.R.S. "Philosophical Transactions of the Royal Society," Series B., Vol. 191, pp. 139–210. A summary of this valuable paper is given in the *Irish Farmer's Gazette*, March 3rd and 10th, 1900, by the present writer, who avails himself of this opportunity of acknowledging indebtedness to the late Sir J. Henry Gilbert for numerous Rothamsted publications, and other information, supplied, and freely used, in the preparation of this book.

Carriers of Nitric Acid.

One of the most interesting discoveries, which the authors record in the Paper, is that the mineral substances taken up by plants, act the part of carriers of nitric acid—the source in plants of the important element nitrogen, the basis of proteids. Thus we read on p. 207:—

"The conclusion was, that, independently of any specially physiological function of the bases, such as that of potash in connection with the formation of carbohydrates, for example, their office was prominently also that of *carriers of nitric acid*; and that, when the nitrogen had been assimilated, the base was left as a residue in combination with organic acid—which, according to the character of the plant, was represented more or less completely by carbonic acid in the ash.

"Further, existing knowledge—as to the condition in which nitrogen is found in soil waters, as to the action of nitrates used as manures, as to the presence of nitrates in still-growing plants, and as to the connection between the nitrogen assimilated and the composition of the ash as has been illustrated—points to the conclusion that, at any rate a large amount of the nitrogen of the chlorophyllous vegetation on the earth's surface is derived from nitrates; whilst, so far as this is the case, the *raison d'être* of much of the fixed base found in the ashes of plants, would seem to be clearly indicated."

Another deduction noted would seem to be that the abnormally dark green colour, and leafy appearance often presented by over-rank vegetation, is the undesirable effect of a preponderance of nitrogenous compounds in the soil, where a sufficiency of the mineral substances, limes, phosphoric acid, and, above all, potash, is wanting—these being necessary, with the soils' nitrogenous contents, to bring about healthy plant growth.

Lime, Potash, and Phosphoric Acid.

From what has come before the reader he will judge of the cardinal importance of supplies of lime, potash, and phosphoric acid in the soil—we are now again dealing with supplies naturally occurring there—the other mineral constituents, however essential, are not so much in evidence as requisites. It is also clear that the presence and comparative abundance of the substances named have a distinctly recognisable bearing upon the question of productiveness; and that the states in which they occur introduce additional elements of variety, in degrees of natural fertility. It accordingly becomes necessary, for thorough acquaintance with a soil, to know not only what substances are present, and the proportions in which they occur, but also the states in which the leading components exist—at least the proportions of them easily rendered available for vegetation, through solution either by water, weak acids, or other solvents. Chemical investigations alone, when exhaustively carried out, can *fully* reveal these facts and circumstances.

It is recognised that soda salts in solution* liberate potash from its complex compounds in soils, and that organic salts of ammonia resembling citrates, act powerfully upon phosphates; *in nature*, however, these solvents do not ordinarily occur in very appreciable quantities. The more commonly occurring solvents, besides water, are solutions of carbonic acid, and weak acids derived from decaying organic matters, which, in effect at least, resemble citric acid. Together with these means of solution, acid sap exudes from the roots of plants, which enables them to extract portions of their food supplies directly from components of the soil. Sachs, who investigated this interesting subject, illustrated the process by etchings which he showed to have been effected upon polished marble which had lain buried. Dr. Bernard Dyer discusses the subject exhaustively, in an elaborate Paper which gives the results of his investigations regarding the substances available in soils as food for plants. † He found that the average strength or corrosive power of the acid-sap of 100 species of plants, belonging to twenty well-known Orders, corresponded to that of a solution of crystallized citric acid containing 0·91 per cent. of crystal. For individual species, the strength was found to be as low as 0·16 per cent. in the leek (*Allium porrium —Liliaceæ*), and as high as 3·69 in *Geum—Rosaceæ*.‡ Taking a citric acid solution of 1·00 per cent., Dr. Dyer estimated that samples of soil taken from various plots of Hoos Field at Rothamsted yielded to the solvent, in the cases of phosphates and potash salts, to the extent set forth in the following Table. The cases selected for our present purpose are those of plots which received no potash nor phosphoric acid manuring:—Plot 1. No manure of any kind for thirty-eight years; 2, treated for this period with ammonia salts; 3, treated for same period with nitrate of soda; 4, with nitrate and silicate of soda; 5, with rape cake; 6, with farmyard manure.

---

* Solutions of soda salts naturally occurring in soils result chiefly from the decomposition of soda felsites.

† Jour., Chemical Society, LXV. (1894).

‡ These observations may be taken as illustrative of the fact that different crops possess in different degrees the power of utilising the mineral components of soils.

Table—Showing Results of Treating with Citric Acid 1 per cent. Soils of Hoos Field, Rothamsted.

Plots.	1	2	3	4	5	6
Total Phosphoric Acid (Anhydride P_2O_5),	·099	·097	·101	·106	·158	·136
Dissolved,	·0055	·0060	·0067	·0074	·0187	·0206
Total Potash K_2O,	1·448	1·418	1·293	1·423	1·384	1·601
Dissolved,	·0036	·0020	·0050	·0042	·0079	·167

Available Plant Food.

It is interesting to notice that the amounts of phosphates extracted by the solvent, are roughly proportionate to the amounts of this component present in the samples; except in the last case, where farmyard manure introduced an element of variation. In the case of potash the proportions are not striking, though they are sufficiently regular to justify the assertion that, as in the case of phosphoric acid also, the larger the total quantity of each present in soils, other things being equal, the greater will probably be the amounts rendered available for plants by the usual acid solvents. It is almost needless to remind the reader that very great differences in available amounts of nutrients may be found in soils, according as samples are taken from a field well treated in the past, or from a field in the same locality which has been ill-treated; also from the head or foot of a sloping field.

Micro-organisms.

Within recent years important discoveries have been made to the effect that certain microscopic organisms, which belong to the border-land of the animal and vegetable kingdoms, play an important part in processes which affect vegetation. Such organisms inhabit air, earth, and water. Of these which are denizens of the soil, some are known to exercise beneficial influences; either in producing elaborations of the very important chemical element nitrogen, already existing in the soil in some form of combination, or artificially supplied to it, preparatory to its being received as a nitrate, by growing plants; or in conferring on certain plants the ability to appropriate the free nitrogen of the atmospheric air which permeates the soil.

A practical application of the discovery, which promises to be of increasing importance to agriculturists, is that of *inoculating* soils destitute of suitable bacteria, with dressings of soils rich in them, or with solutions or preparations, to promote the growth and development of different leguminous crops.

Results illustrative of the effect of such processes are given in a pamphlet* by Dr. Miller of Rothamsted, in which experiments by Dr. Salfield of Bremen are referred to. The following illustration is reproduced here, with permission of Dr. Miller and Dr. Salfield's publisher—M. Heinsius Nachfolger, Bremen.

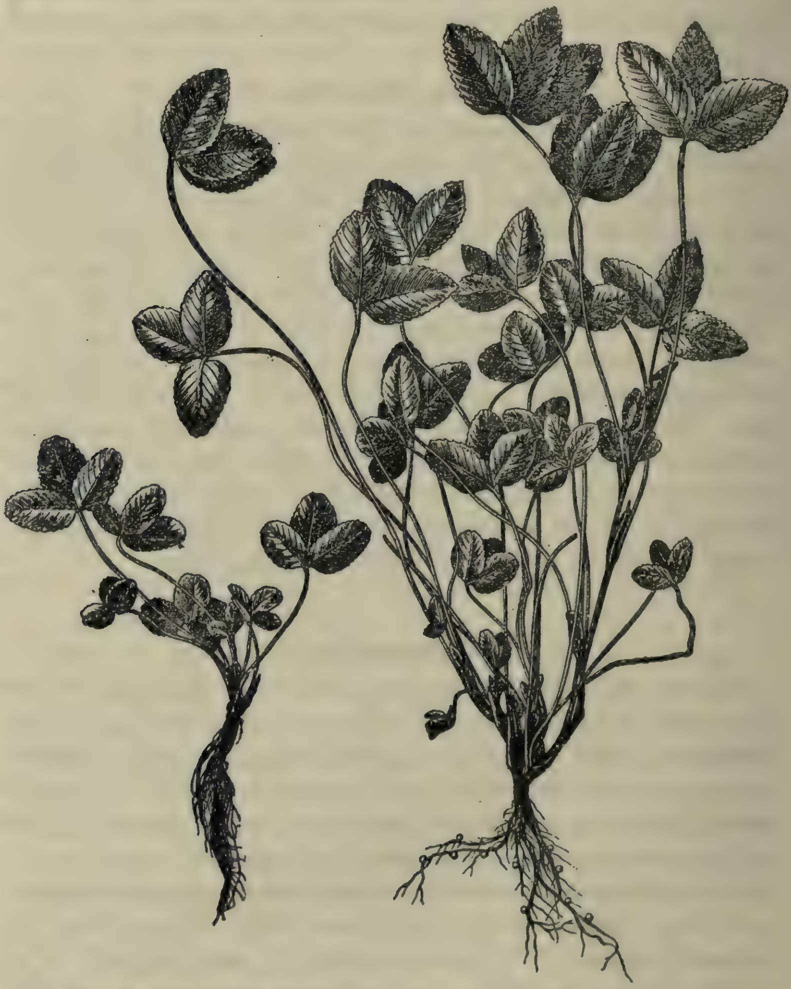


Fig. 4. Effects of inoculating soil with micro-organisms. A. Alsike clover (half natural size) from soil not inoculated. B. Alsike clover (also half natural size), showing root-nodules where the bacteria colonize, from soil inoculated with 8 cwt. of marshy soil per acre.

---

* "Soil Inoculation" (p. 4), by N. H. J. Miller, PH.D., of Rothamsted; also p. 18.

CHAPTER II.

Rocks, and their Lithological Characters.

The ground traversed in the preceding chapters is more or less familiar to the agricultural student. The soil has there been considered chiefly in regard to its characters, contents, and capabilities, rather than its origin. It is now proposed to consider more particularly its origin, and, in doing so, to trace the wider variations assumed by the soil, owing to the differences observable in the rocks which compose the earth's crust. Of these it is scarcely an exaggeration to say the varieties are well-nigh endless. They nevertheless admit of being grouped in various ways; and it will be convenient for the purposes of this book to arrange the chief types of rock to be met with in the country, according to their origin, composition and physical characters. This grouping is adopted in the accompanying table, and the reader may be reminded that any classification of rocks must necessarily be artificial, since gradations may frequently be traced from species to species and class to class.

Stratified Rocks.

AQUEOUS.	*Mechanical Origin,* .	Clay (marl), shale, slate, *mica-schist.* Sand, sandstone, grit, *quartzite,* with associated conglomerates.
	Chemical Origin, .	Rock salt, gypsum, travertine.
	Animal Origin, . .	Limestone, dolomite, *marble.*
	Vegetable Origin, .	Peat lignite, coal, *anthracite*, and *graphite.*

Crystalline or Non-Stratified Rocks.

IGNEOUS.	*Volcanic,* . . .	*Acid.*	Felsite, trachyte, obsidian, ash.
		Basic.	Andesitic and basaltic lavas, ash,
	Plutonic, . . .	*Acid.*	Granite, felsite, syenite, *gneiss,*
		Basic.	Diorite, gabbro, basalt, dolerite, *hornblende-schist, epidiorite, serpentine.*

It would be outside the present purpose to enter upon a detailed description of the rocks named above. For such the reader is referred to text books on Geology. Nothing more can be attempted than to notice a few special points concerning them, particularly the manner in which their lithological character affects agriculture.

Aqueous Rocks.

Clay, (Marl), Shale, Slate, *Mica Schist.*

Hydrated silicate of alumina is the basis of all the rocks of this group, and each type is liable to considerable alterations. Thus specimens of each kind mentioned may contain variable proportions of sand (silica), and on *weathering* (*i.e.*, disintegrating), may yield sandy loams; but usually strong clay soils. Again, these rocks may contain potash-felspar either in recognizable particles or as impalpable mud, which would render the soils derived therefrom rich in potash. Others, again, may contain certain proportions of carbonate of lime, and yield soils more or less calcareous; others, sulphates, chlorides, and phosphates. Neither silica nor alumina furnishes essential plant food, so that the substances named, which may be deemed accessory to clay rocks, are those which impart value to soils derived from them.

Marl is characteristically a calcareous clay. A large area of red marl encircles the basaltic plateau of Antrim and Londonderry, as will be seen later on. Deposits originally formed at the bottoms of lakes in central Ireland, and now to be observed covered perhaps in parts with turf, are of this nature, and may contain fresh-water shells testifying to their origin. The amount of carbonate of lime in such marls is often large, and constitutes them valuable manures. Some so-called marls may be met with under circumstances similar to the above, which are non-calcareous—will not effervesce with strong acid (hydrochloric). These, and such as are poor in the carbonate, are usually worthless as manures.

Shale is moderately hardened clay, which, when dug, or broken up with a hand-pick, softens on exposure to the atmosphere. It may be blue, dark gray, or black, according to the quantity of organic matter contained therein. This may be present in such quantity as to render the shale bituminous, and profitable as a source of petroleum. Such shale occurs in North-east Antrim. Shale also frequently contains marcasite or pyrites, sometimes in diffused grains or in yellow cubical crystals. As this variety weathers, the sulphide of iron is decomposed, and alum is formed, as in the case of the rock along the coast of Clare and Limerick.

Slate is a more indurated (hardened) form of clay, in which the substance has taken up a thinly fissile structure. This structure is known as cleavage, and renders slate-rock easily split into thin laminæ. Only after very prolonged exposure does slate resolve itself into friable mould or clay—its original state—for which reason it is valuable for roofing purposes. Much of this species of rock is to be met with in South Mayo, East Clare, Tipperary, Cork, Kilkenny, Wicklow, Wexford, and Waterford.

Mica-schist, or, as it has sometimes been called, *mica-slate*, is a crystalline rock; its fresh-cleaved faces glisten in the sunlight—hence the name of the mineral mica. Its character marks a high degree of alteration which some original rock has undergone, in most cases probably shale. Because of the alteration, mica-schist is grouped in the preceding Table, and set forth in italics, with gneiss, quartzite, and marble, all of which are known as *metamorphic rocks.* These form large tracts throughout Galway, Mayo, Donegal, and Tyrone, and other parts of Ireland. Mica-schist forms clay and fine sand on ultimate weathering; but its crystalline constituents yield so tardily to the natural forces of disintegration that, even when the rock contains a low percentage of the sand-forming ingredient, silica, the resulting soils are open and friable.

A few analyses are here given* to show the general correspondence in composition prevailing amongst the members of this group. Other analyses of slates and mica schists will be found on pages 127, 139, of the present work.

1. Tamworth "black clay."
2. Stourbridge "burnt clay."
3. Buxton "disintegrated shale."
4. Buxton "hard shale."
5. Co. Tyrone, "quartz slate" (locality not given).
6. Co. Tyrone, "imperfect clay slate" (locality not given).

TABLE showing Composition of certain Clays, Shales, and Slates.

Components.	1	2	3	4	5	6
Silica.	57·45	67·69	49·78	57·00	67·02	52·45
Alumina, ...	37·93	27·91	29·07	24·33	14·92	12·01
Peroxide of Iron, ...	2·2	2·35			11·36	17·92
Manganese oxide, ...	—	—	1·43	—	—	—
Lime, ...	0·92	·63	·40	1·88	0·73	7·72
Magnesia, ...	0·15	·11	1·11	2·10	3·56	
Potash, ...			5·37			3·82
Soda, ...						
Iron disulphide (Pyrites),	—	—	—	2·36	—	—
Water, ...	—	—	12·84	12·27	2·41	6·88

Sand, Sandstone, Grit, *Quartzite.*

The basis of this group is silica, as that of the former group is silicate of alumina; and, as met with in many formations, and in many places throughout Ireland, its members present a great variety of characters, dependent upon the nature and amount of extraneous substances. Specimens may be argillaceous, and graduate into the clay rocks; or calcareous, graduating into arenaceous (sandy) limestone; or yet again felspathic. Silicious sand and sandstone, if pure, would yield soils utterly barren; they are altogether dependent upon substances which may be considered accessory, to render their derivative soils fertile. The same remarks apply to quartzite, which decomposes with exceeding difficulty. The texture of the members of this group depends upon the size of the particles composing them. They may be coarse sandstone or pebbly grits; and these may range in coarseness into conglomerates, which may contain pebbles up to a foot or more in diameter. The pebbles of conglomerates (or "pudding stone") are usually rounded; when they are markedly angular, the rock is known as a breccia.

---

* Taken from "Portland Cement, its Manufacture and Uses," by Henry Reid, London, 1887, pp. 89, 97, 105, 106.

The two groups just described are frequently found associated, a member of one superimposed upon a member of the other, and so on; thus layers of sand and clay occur alternately, sandstone and shale, grit and slate, and quartzite and mica-schist. Sometimes the arenaceous (sandy) group may predominate in a locality or region, and sometimes the argillaceous group; but even in such cases beds of the contrary kind are rarely wanting.

Soils resulting from the disintegration of these rocks, consequently, consist of mixed debris, being sandy or loamy according as arenaceous or argillaceous rocks originally predominate, in any given locality.*

Building Stone and Road Metal.

Some choice building stone is found in this group at many points throughout Ireland. The sandstone quarries near Mountcharles in Donegal, and at Altnabrock, near Lisnaskea, in Fermanagh, have yielded much prized material—easily wrought, fine grained, bearing a good weight, and lasting well. Much of this stone often used for roads is too easily crushed, and forms a weak surface for much or heavy traffic. A large proportion of the hard, fine-grained grit occurring amongst the Silurian rocks is well suited for road-metal. The same may be said of quartzite; and while both are locally used for building purposes, neither is likely to be much sought after for general use.

Rock Salt, Gypsum, Travertine.

Deposits of rock-salt and gypsum—believed to have been laid down from the evaporated waters of ancient lakes—occur in the

---

* It should be explained that the modifications which rocks have undergone in the cases of *mica-schist*, &c., to which the term metamorphism has been applied, seem to have taken place when the rocks were buried deep within the crust.

The circumstances under which those rocks have been rendered visible at the present surface will be explained in a future chapter. (See pages 28, 44, *et seq.*)

"New Red Marl" which lies to the north of Belfast Lough. Gypsum also occurs near Kingscourt, as will afterwards be described. Besides serving useful ends in the economy of agriculture, these substances are of additional commercial interest as sources of purified salt and plaster-of-Paris, respectively.

Travertine (calcareous tufa) is a material precipitated from evaporating water strongly impregnated with carbonate of lime. It forms incrustations on moss, twigs, &c., over which such water trickles; and sometimes it forms thick beds on the surface around calcareous springs and on sloping banks of limestone gravel, along which water exudes, after sinking into the ground at a higher level. This material, sometimes known as "marl," is largely used as a calcareous manure in different parts of the country, and is almost as effective as lime, being carbonate of lime in a finely divided state. Water trickling over the faces of limestone rock forms a deposit of this substance; and drippings from the roofs of limestone caverns, and the soffits of arches, form pendulous spikes called stalactites. The floors beneath, if dry and undisturbed, become also covered with layers of the same material, known as stalagmite.

Limestone, Dolomite, *Marble.*

These rocks occur in layers or beds like those of the first two groups, and, like them, were originally formed on ancient sea-floors, through the operation of the coral-polyp and other forms of marine life. Dolomite and marble are the products of subsequent changes, and do not always manifest the stratification or bedding common to rocks of sedimentary origin. All may contain extraneous matter (impurities), clay, and sand in various proportions, and may be gray, yellow, blue, and black; dolomite being usually yellow, and marble frequently white. All weather freely, particularly the more earthy and sandy varieties.

Limestone.—The basis of this rock is carbonate of lime (56 parts of lime to 44 of carbonic acid); but it may graduate into stone in which very little of the carbonate exists, such as shaly or sandy limestone, or calcareous shale and grit. Besides containing a large quantity of the valuable nutrient, *lime*, phosphoric acid is usually present, though always in small quantity, as may be seen by the analyses given on page 89. Even traces of this important accessory in a rock which dissolves with comparative rapidity,* represent a considerable supply per acre, an additional advantage being that it is presented to vegetation in an effective form.†

---

* See results of Experiments on page 9.

† Additional remarks upon this point will be found on page 88

The process of lime-burning consists of expelling by means of heat, the carbonic acid which the stone contains. If the stone be pure, 100 parts will be found to have lost nearly 44 parts by weight in the process; and the residue is rich quicklime. Earthy limestone, well burnt, leaves the earthy component mingled with the quicklime; on account of which the residue slakes less readily; it is not so valuable as rich lime for agricultural purposes, but for building it is to be prized, as it sets harder, makes a good bond, and if the earthy matter be mostly or entirely *clay*, the "lime" resembles cement and sets in water: it possesses hydraulic properties.

A few analyses of limestones, tabulated from data given by Reid* on the authority of names mentioned, will enable the reader to judge of the degrees of purity characterising some Irish specimens; and of the quantity of earthy matter found in some others. For the purposes of comparison, analyses of two varieties of Lias limestone are added, from Aberthaw, which yielded hydraulic lime, famous as having been used by Smeaton in the construction of Eddystone Lighthouse.

1. White Limestone, Cork (Reid).
2. " " " shelly (Reid).
3. Grey " Limerick (Reid).
4. Limestone, Brown's Cliff, Carlow (Griffith).
5. Limestone (Calp) Dublin (Knox).
6. " Newton Gore, Cavan (Jones).
7. Lias Limestone, Larne, Antrim (Hodges).
8. " Aberthaw.
9. " "

TABLE I.

—	1.	2.	3.	9.
Carbonate of Lime, . . .	99	96	96	86
" Magnesia, . .	–	2	–	2
Silica, ...	–	2	2	8
Alumina, ...	–	1	–	1
Peroxide of Iron, . . .	–	–	1	2
Water and Loss, ...	1	1	1	1
	100	100	100	105

TABLE II.

—	4.	5.	6.	7.	8.
Carbonate of Lime, . . .	95·0	68·0	65·10	71·66	86·2
" Magnesia, . . .	–	–	1·40	2·67	–
Silica and Alumina (insoluble—"clay")	4·5	18·0	32·85	14·61	11·2
Alumina and Oxide of Iron, . .	–	9·5	·66	9·42	–
Organic matter (? and water), . .	–	4·5	–	–	–
Water and Loss, ...	–	–	–	–	2·6
	99·5	100·0	100·01	98·36	100·0

---

* "Portland Cement, its Manufacture and Uses," Henry Reid, 1877, pp. 79, 68, 58, 56.

Dolomite.—This rock is a double carbonate of lime and magnesia (56 parts of lime to 28 of magnesia). It is usually a product of alteration of limestone, a portion of the lime having been replaced by magnesia. Many so-called dolomites contain a smaller percentage of the latter substance than would justify the appellation, and should more strictly be called dolomitic limestones. Limestones usually contain small quantities of magnesia. Analyses of dolomitic limestones, and of one nearly approaching a dolomite in composition, will be found on page 87.

Marble.—True marble is rarely to be met with in Ireland. It is, as previously stated, an altered limestone, and crystalline. Ordinary limestones of various kinds when polished are termed marbles*; and serpentine dressed in a similar manner for ornamental purposes is also so called. In neither case, however, is the term quite appropriate.

Some varieties of limestone make excellent building stone, and last well. For roads, limestone at best is a second class material, it dissolves too readily and is easily crushed. The use of the earthy "Calp" limestone is accountable for muddy roads near Dublin, and in other parts of the country.

Peat, Lignite, Coal, *Anthracite, Graphite.*

Brief reference has been made to peat in the opening pages; and a chapter will hereafter be devoted to the deposits of this substance throughout Ireland; it will therefore here suffice to remind the reader that peat is but a recent representative of the other members of this group, which sometimes occur in deposits of great thickness; though it is probable that forest growths entered more largely into the composition of coal seams, than they do into that of modern bogs.

In the processes of transformation from vegetable matter into brown and black peat, and equally into lignite, coal, &c., oxygen, combined with certain proportions of carbon and hydrogen, escapes, in carbonic acid and carburetted hydrogen gases, and water, with the result that carbon tends to increase proportionately in the mass, the colour deepening meantime, until the stage of transformation represented by graphite is reached. Peat, therefore, would stand at one extreme of the group, and graphite, which consists almost wholly of carbon, at the other.

---

* Prof. W. N. Hartley, F.R.S., in the Scientific Proceedings of the Royal Dublin Society, Vol. V. (N.S.), 1887, p. 488, gives the results of two analyses of the Kilkenny "Black Marble," each of which shows 91·84 per cent. of carbonate of lime, together with small percentages of iron, copper, and magnesic oxides, silica, water and organic matter. When limestone contains iron oxide in large quantity it forms a beautiful pink "marble," such as that quarried at Midleton in Cork.

It is supposed that, through waste of substance in the transformation, as well as the compression which the materials have undergone, it has taken five to ten feet of vegetable matter to form each foot in thickness of coal.

Irish Coals.

Anthracite, the form in which coal is found in the central Ireland Coal-field, as in Wales, contains 80 to 90 per cent. of carbon, and ash varying up to 10 per cent. or thereabouts. It gives a great heat, but is objectionable for domestic purposes, on account of its containing sulphur in unusual proportions. Lacking in hydrocarbons, it does not give much flame, though it burns freely. The coal obtained at the Coal Island Field, near Dungannon, is rich in hydrocarbons, and is classed with " bituminous " varieties. That of the county of Leitrim is for the most part earthy, leaving much ash when burnt, and is in consequence, of low heating power, though some samples are fairly pure.

IGNEOUS ROCKS.

Amongst the most interesting components of the earth's crust are those to which reference is now to be made. With the exception of granite and basalt, they do not occupy extensive areas throughout Ireland; and as soil producers they do not rank as the most important. On these grounds, therefore, they might be cursorily disposed of. It is believed, however, that all sedimentary or aqueous rocks have been derived from igneous, or from earlier sedimentary ones; and that prior to the formation of any sediments, only rocks belonging, or related, to the igneous class existed on the pristine globe. This circumstance invests igneous rocks with a peculiar interest, and establishes their claim to a somewhat detailed notice, even in an agricultural memoir. Their common characteristic is that, as their name implies, they were once molten magmas, of different chemical compositions, which solidified in various forms. Some are obviously crystalline, some micro-crystalline the structure being discernible only with the aid of a lens; and others are so compact that a microscope is necessary for a discernment of their structure. No true bedding is to be observed in these rocks, though an arrangement both of the crystalline components, and of the mass, as in platy structure, may sometimes be observed.

Crystalline Components.

The igneous rocks are aggregates of recognizable minerals, most of which occur in crystalline form in the complex mass of each rock species. The grouping of certain minerals together is what gives distinctive character to the types, and, in addition to such characteristic or essential minerals, others, which are deemed accessory, occur in the rocks, one of the principal of which, from the agriculturist's standpoint, is *apatite.* This mineral is a complex compound of lime, phosphoric acid, fluorine, and chlorine, and contains a high percentage of phosphorus. It occurs in small quantities in rocks belonging to both the acid and the basic groups, but more abundantly in the latter than in the former.

The following table gives the approximate percentage compositions of the chief minerals found in rocks of the igneous class. The figures are the averages of five analyses in each case, as given in Dana's "System of Mineralogy."

TABLE OF MINERALS.

Name.	Silica.	Alumina.	Potash.	Soda.	Lime.	Magnesia.	Iron Oxide (ferrous.)	Iron Oxide (ferric.)	Manganese Oxide.	Fluorine.	Water.
Felspars.											
Orthoclase, . .	65·6	18·1	13·9	1·2	·61	·07		·20			
Oligoclase, . .	63·7	23·1	1·1	18·6	3·4						
Albite, . . .	67·3	29·1	·4	11·4	·66						
Labradorite, .	55·6	27·1	·4	6·1	19·37	·05		·40			
Anorthite, . .	44·5	33·6	·5	·14	17·08	1·51		·96			
Micas.											
Muscovite, . .	44·64	36·68	9·79	1·31	·17	·25	1·01	·95		·16	5·13
Biotite, . . .	40·51	6·28	8·65	·96		23·91	3·53	3·06		·62	1·91
Hornblende, . .	39·81	15·07		1·39	13·01	1·23	5·61	10·73	1·58		
Augite, . . .	48·54	6·31			20·95	14·45	5·81	3·96			
Apatite,[*] . . .		·29			55·21	·33		·57		2·09	·32

Volcanic and Plutonic Rocks.

Reverting to the classification of the rocks at the opening of this chapter, it will be seen that those of igneous origin are separated into *volcanic* and *plutonic* sub-classes; and each of these again into acid and basic groups. This last division depends upon the proportion of silica which the rocks contain—all containing more than 60 per cent. (according to Bunsen) being *acid*, and those showing a less percentage, *basic.* An intermediate group is added in works on petrography.

Volcanic rocks, it is almost needless to say, are those which have been ejected at the surface, in the forms of lavas, ashes, or agglomerates, from deep-seated sources within the crust, through vents in the same; while plutonic rocks are those which in their molten condition have failed to reach the surface at the time of their injection. These were forced into subterranean fissures, and often seem to have formed great masses of viscid material beneath tracts of unfused rock. In many cases they probably formed the roots of volcanoes. A close correspondence between the rocks of volcanoes and plutonic origin confirms this conclusion, for which reason the subclasses will be described in detail conjointly. Denudation, it may be added (*i.e.*, superficial waste), continued throughout ages, has removed portions of the crust, beneath which some plutonic masses lay concealed, and has afforded the opportunity of now studying them. In many instances it may be seen, as shown in the sections given on pp. 51, 52, that rocks of sedimentary origin, or even more ancient plutonic masses, abut against the newer intrusive rocks, in such a manner as to suggest that the former succumbed to fusion and probably supplied material to the adjoining once-molten mass. The following tabulated view of the principal acid and basic rocks, together with their essential and accessory minerals, has been prepared chiefly from Fouqué and Lévy's work, *Minéralogie Micrographique.* It will, with the aid of the previous table of minerals, enable the reader to judge of the fertilizing substances which are furnished by the different rocks.

---

[*] Contains phosphoric anhydride (acid less water), 41·53 per cent. plus constituents given in the table.

TABLE OF PRINCIPAL IGNEOUS ROCKS.

	Rock.	Essential Minerals,	Accessory Minerals.
ACID.	Granite,*	Orthoclase or Microcline, quartz, mica.	Oligoclase, albite, hornblende, sphene, apatite, magnetite.
	Quartz-felsite.	Orthoclase, quartz, mica, . .	Do. do.
BASIC.	Diorite, .	Amphibole (hornblende), or mica, oligoclase or labradorite, magnetite, and quartz (occasionally).	Pyroxene, apatite, ilmenite, anorthite (lime felspar).
	Gabbro, .	Pyroxene (diallage, augite) labradorite, magnetite.	Amphibole, mica, apatite, oligoclase, anorthite, ilmenite.
	Andesite, .	Amphibole, or pyroxene, or mica, and oligoclase or labradorite.	Apatite, ilmenite.
	Basalt, or Dolerite.	Labradorite, pyroxene, magnetite,	Olivine, apatite, ilmenite.

Acid Group.

Granite, *Gneiss.*—These rocks are crystalline aggregates of felspar, quartz and mica, which vary considerably in relative proportions. The felspar is chiefly orthoclase, which may be white, flesh-coloured, or red, giving to the rock corresponding tints. The quartz is usually colourless and limpid, and the mica white, or

---

[*] The terms *Granulite* and *granitite* are also used, but are omitted from the Table, because the former is defined differently by authorities, and the latter is not in frequent use. By granulite, French authorities signify muscovite-biotite granite, which the English regard as normal granite; and, by it, the latter authorities mean a microgranite. *Granitite* is a granite with only black mica (biotite).

black, or dark green, weathering brown. In the cases of some granites—those forming the Donegal mountains for example—the components exhibit a rude arrangement simulating stratification—giving to the rock a streaky appearance known as foliation; and this structure is especially pronounced in some regions. In such cases the granitoid rock receives the name of *gneiss*. Besides the accessory minerals given by Fouqué and Lévy, tourmaline, and occasionally beryl are to be met with in granite.

Granite and gneiss yield unpropitious soils, in many cases little better than coarse sand, though even this is applied with advantage as top-dressing on the peaty soils of North-west Donegal. Potash may be counted upon in the disintegrated materials, together with minute quantities of soda, lime, and magnesia occasionally. In certain cases weathering and disintegration have proceeded to a great depth and extent, producing, when extreme conditions are reached, a fine sandy earth no longer containing the potash and soda of the felspars, but consisting of a mixture of kaolin (hydrated silicate of alumina) and silica.

Granite for Building and Road-making.

Little need be said here concerning granite as a building stone. Its value for this purpose is well known. Large quarries throughout the granite areas of Dublin, Down, Donegal, and Galway have yielded much valuable material; and are alike capable of development and worthy of encouragement. Granite also makes fair paving setts, though they wear smooth; and as ordinary road-metal, the coarsely crystalline varieties give way to heavy traffic too readily. The finer and more compact varieties, however, wear well and do not succumb to the solvent action of rain-water.

Felsite, a hard, often compact and splintery rock, sometimes quite flinty in texture, in colour light gray, pinkish, purplish, or slate-coloured. It is often vesicular, and then may contain calcite in its numerous cavities. *Rhyolite* and *obsidian* are volcanic rocks of similar composition to felsite; the former is rough to the touch, *i.e.*, in texture, the latter a volcanic glass. The chief difference noticeable between volcanic and plutonic felsites is the greater liability of the latter group to be coarse in texture, porphyritic (containing felspar crystals set in a compact matrix), and rarely vesicular. Felsite frequently contains quartz in globular particles, and flakes of mica.

The various felsites, including rhyolite and obsidian, weather with more or less rapidity, and yield earths in which potash is almost the sole leading fertilizer to be reckoned upon. The vesicular varieties, containing calcite, supply lime in addition; and the proportion of phosphoric acid, from the accessory apatite, is inappreciable.

Felsites are not suited for building purposes. They break short, and are difficult to dress. Being very hard, they form good road material—breaking into wedge-shaped fragments which take a good bond.

Syenite is a granulo-crystalline rock, consisting of felspar, and hornblende (and sometimes augite); it resembles granite as a source of soils, for its chief component is the potash-felspar. For this reason it is here placed immediately after the acid group, though it is usually described with the diorite family, and is intermediate in silica-percentage between granite and diorite. Syenite is of rare occurrence in Ireland. Granite with hornblende is sometimes so named.

Basic Group.

Andesite like Syenite occupies an intermediate place between the acid and basic groups, and is composed generally of soda-lime felspar, and hornblende or augite.

Rocks of this species are largely represented in the South-east corner of Ireland, and in the West. They form good road-metal and paving setts, but are not an approved stone for building.

Diorite is usually a more basic rock than the previous one, but resembles it in composition; both may contain a proportion of quartz, and range with the acid group; or be devoid of free quartz, and range with the basic group. Their value to agriculture is decided by the ability to yield to soils a greater proportion of lime than the acid rocks, as well as, in many cases a proportion of phosphates.

Gabbro, Basalt, Dolerite.—These rocks resemble each other in chemical composition, the plutonic varieties being coarser in texture, more manifestly crystalline than the volcanic. Basalt, being much more widely distributed in Ireland than the other varieties, may be described in detail. It is dark in colour—almost black—micro-crystalline, often very compact, and generally homogeneous in texture. Very often it abounds in small cavities which are filled with calcite, as may be ascertained by its effervescing with acids. The cavities are more frequently filled with *zeolites*, which do not effervesce. During the solidification and cooling, basalt often assumes a columnar structure, as is to be seen in the well-known example presented in the Giant's Causeway.

The basic igneous rocks form good road-metal. They are also used as building material; and basalt takes fair dressing. The dark colour of this rock, however, is almost prohibitory of general use.

Reference to the tables of rocks and minerals shows that clays derived from basalt, and corresponding plutonic rocks, varieties of which weather rapidly, may be expected to be moderately rich in lime. This substance being, however, in combination with silica, is not so readily available to crops as it is in the more soluble compound with carbonic acid—limestone. Basalt contains little potash, more soda, and is comparatively rich in phosphoric acid. Hence soil derived from these rocks is fairly endowed with elements of fertility. It is stated in Johnston's "Elements,"* that such rocks (basic lavas and traps) "crumble with various degrees of rapidity when exposed to the air; and in Italy and Sicily often form soils of the most fertile description." They may even, "when in a decayed state, be advantageously employed for the improvement of less fruitful soils." Elie de Beaumont ascribed the richness of soils after such rocks to their contained phosphates. It was formerly supposed that the alkalis present accounted for the fertility. But the lesser degree of fertility of granite-derived soils, wherein alkalis are abundant, shows that these ingredients are not the criteria.

Hornblende Schist, Epi-diorite, Serpentine.—What has been stated in the last two paragraphs applies to the rocks of this group, with the exception of serpentine.

In serpentine, magnesia abounds to the almost entire exclusion of lime. It forms a highly ornamental building stone; and is so soft that it can easily be cut and turned in a lathe; for this reason, too, it is not suitable for heavy work. It will not bear a great crushing weight.

These rocks are the representatives of some resembling, if not originally identical with, those of the basalt group. They have undergone modifications which render them little liable to decay; they are, in consequence, usually seen standing out in relief above the rocks which surround them, and are often devoid of earth covering.

The tables of analyses of igneous rocks, given on pages 127, 128, may be referred to for a comparison of the fertilising substances yielded to soils by those of the acid and basic groups, respectively.

---

* *Op. cit.*, p. 130.

Rocks of igneous origin are sometimes spoken of as trap rocks, or, shortly, as traps; and, by some, the term is erroneously restricted to those close-grained varieties which, excluding granites, are of intrusive, in other words, of plutonic origin. The term is derived from the manner in which layers of igneous rocks are disposed, lying one above another, and disintegrating in such a manner as to suggest steps of stairs. This arrangement is most frequently seen amongst intrusive sheets and lavas, as may be observed in the illustration of Antrim basaltic sheets given on p. 122, a view of the coast cliffs near the Giant's Causeway.

It will be perceived that what has occupied us in this chapter has been the petrographical character of rocks, as these are discernible by means of *laboratory methods.* Without this knowledge it is impossible at sight to tell the composition of each kind, what fertilizers it can afford, and in what degree a soil derived therefrom is endowed with useful components. It is therefore the necessary basis of agricultural geology. What will come before the reader in the next and following chapters is a review of rocks as seen *in the field*, their natural distribution, and what we may call their deportment as regards the formation and endowment of soils.

Old Sea-stack and Cliffs of raised Coast-line near Castle Robin, Island Magee.*

---

* From explanation of Sheets 21, 28, 29, page 34.

CHAPTER III.—Superficial Deposits.

From the foregoing chapters it will be understood that the accumulations of detritus which clothe the solid crust, whether they be deep or shallow, are the result of rock-disintegration which has been going on for long periods of time; and the nature of the detritus, if it lay undisturbed by natural causes, would, as a general rule, be determined by that of the rock underlying it. The conditions under which Irish soils and subsoils occur are, however, not of this ordinary character, except in some limited areas; for which reason specific means of representing them—soil maps—would be desirable, as mentioned in the opening chapter. Agricultural maps have been advocated, to give detailed information respecting soils, crops, pasture, &c., and such have been prepared in the Department of Calvados, in France, by M. de Caumont; and by others following him.* It is easy to understand how the character of information thus given, though to a certain degree useful, might become so diffuse as to be of questionable practical value; and so high an authority as M. Risler does not consider others than detailed geological maps necessary, while strongly recommending these for agricultural purposes. Ordinary geological maps show the solid strata of a country. Those published on a scale of one mile to an inch, and the map accompanying this treatise, on a scale of ten miles to an inch, show besides, in a fair measure of detail, the areas covered with superficial deposits. Maps of this kind, or on a larger scale, would probably suffice for the country described by M. Risler—France; for there, the clay-soils and subsoils rest upon their parent rock, with little exception; and from this their nature and resources may be judged. In more northern climates, including that of Ireland, glacial conditions prevailed, and have obscured the relations between the rock-formations and the detritus that covers them. Here, therefore, geological maps would not suffice,† though serving as a basis for maps which would suggest the approximate nature and resources of soils. The want of such cannot fail to be increasingly felt with the growth and extension of technical knowledge and inquiry. The circumstances which render them necessary, for a correct and intelligent view of soils, are exemplified in what follows.

---

* See appended notes, pp. 279 *et seq.*

† The maps issued by the Geological Survey in England and those in preparation in Ireland are described in Appendix, p. 282.

Transported Soils.

It is not unusual, in Ireland, to find detritus derived from one set of rocks overlying another set; for example, materials derived from limestone strata over granite, as in parts of the county of Dublin, and covering grit and slate in parts of Wicklow and Wexford; and *débris* of mica-schist over granite in Donegal, and so forth. We need not, therefore, be surprised to see it stated* that "the relations between the soils and the underlying rocks is such that any classification of the rocks . . . . can be of no agricultural importance whatever." This statement is more sweeping than a careful study of the facts justifies; but it serves to illustrate how illusory is the hypothesis that the geographical disposition of rocks necessarily in all cases determines the nature of the superincumbent soils. The abnormal circumstances, as mentioned above, are to be accounted for in Ireland, as in the rest of Northern Europe, by the transplacements of rock-detritus through the agency of land ice, and, possibly, of icebergs, during a comparatively recent geological period. This movement of superficial material has been attended, in Ireland, with marked advantages to the agricultural interest, such as

(1) A greater area of extension than would otherwise obtain, of fertilizing materials;

(2) A mixing of materials from different sources, which generally conduces to fertility.

Wide Extent of Limestone Detritus.

With regard to the first point, detritus known as "limestone gravels," has been distributed over rocks which contain no limestone, and a comparatively small admixture of carbonate of lime, throughout large tracts of Dublin, Wicklow, Wexford,† Carlow, Kilkenny, Tipperary, Cork, King's and Queen's Counties, Monaghan, and Meath, imparting an enhanced value to the soil of some 750,000 acres, or more, in the aggregate.

With respect to the second point, the beneficial effects accruing from the intermingling of various kinds of *débris* is dwelt upon by Dr. Fream,‡ who points out that the most fertile veins of land in England follow the junction of different geological Formations.

---

* By the author of "A Guide to the Principles of Land Valuation." Ponsonby, Dublin.

† So highly calcareous are these transported materials that in Wexford they are known as "manure gravels."

‡ "Soils and Their Properties," pp. 104, 105.

The proverbial fertility of the Golden Vale, in Tipperary and Limerick, is doubtless, in part, due to the mingling of materials derived from Old Red Sandstone, Silurian and igneous rocks, with those derived from the limestone of that region. Sir R. Kane* attributes the fertility of the Vale to this cause, and points out that the soil of the Lagan valley, which is also notably fertile, owes its condition to a diversity of materials. The fattening lands of Meath and North Kildare—"the richest soil" which Wakefield "ever saw turned up with a plough"—are over limestone; but, being transported soils of considerable depth, contain an admixture of *débris* from other sources.

Glacial Drift.

The transplacements of detritus mentioned are, to a great extent, accountable for the present distribution of soils and subsoils, which we may now speak of combinedly as *Drift*; and, in this aggregate view, we may think of it as an extensive covering made up of a confused mixture of stones and earth, robing two-thirds of the country or more, lying chiefly in the low grounds—where, however, the naked rock presents itself at many points over small areas—and in places rising to heights of 1,500 or 1,600 feet on the hill sides,† softening the surface-outline, and otherwise modifying the landscape. Well-nigh all the land of much agricultural value in Ireland falls below the 1,000 feet contour. It was calculated by the officers of the Ordnance Survey that 1,672 square miles lay above that level, half of which may be regarded as waste mountain land. Of the remaining 30,836 square miles between the 1,000 feet contour and the sea, over 20,000 square miles are covered with Drift, though parts of this area are concealed by bog, alluvial deposits, and the waters of rivers and lakes. It is thus manifest that the circumstances of the Drift affect agriculture to a great extent, and should be taken full account of, either in respect of the economic treatment of the soils, or for the purposes of valuation.

Upper and Lower Drifts.

The great mass of Drift in certain places (and it attains, or may even exceed, a thickness of 100 feet) may be of a character totally different to such material as the local rocks could yield, as already mentioned. It also frequently happens that the uppermost portion differs from the main mass and may form a distinct layer thereupon.

---

* "Industrial Resources," 1st Ed., p. 249.

† Rev. Maxwell Close, M.A., recorded the occurrence of transported blocks on the Dublin Mountains, at a height of 1,760 feet. Jour. Roy. Geo. Soc., Ireland, Vol. 1866, p. 10.

Such a layer may be clearly seen in the cuttings along the recently-constructed railway line connecting Westport and Newport, in Mayo—the layer being made up of sandstone *débris* almost devoid of limestone, while the main mass of the drift below consists chiefly of limestone detritus. Similar conditions may be observed at Bantry, and at Grange Con, in West Wicklow.* In many sections, curious to say, the upper layers may consist chiefly of detritus such as the rocks of a locality might yield, while the lower portions of the Drift are formed of materials foreign to the district—a state of things accounted for, in general, by the protrusion above the level of the lower Drift, of ridges and knolls of local rock, whence the higher Drift was derived.

When the deepest Drift consists of materials especially valuable in an agricultural sense, for instance, of limestone boulder-clay, the existence of a layer of unpropitious material above it, tends greatly to modify, if not to nullify, its worth. Where this layer is of insignificant thickness, plants may draw directly upon the store of rich materials below; lucerne, sainfoin, and other deep-rooting plants may thrive when the unpropitious layer is thicker; and even in this case capillary attraction may give sustaining aid to shallow-rooting crops. Where, however, the uppermost layer is several feet in depth a mine of agricultural wealth may exist beneath, without imparting any benefit to the land, unless where, on sloping ground, the lower-lying fields are enriched by percolating waters form the deeper Drift, this nutrient-charged water acting as an unobserved irrigating agent in seasons of excessive rain. One other circumstance, frequently met with, may be noticed, namely, that the beneficial materials which form the body of the lower Drift may commingle with those which form the upper, and with salutary effect, proportionate to their frequency.

These considerations are all of obvious moment to the agriculturist,† and must be kept in view in attempting to judge of the true nature and resources of the soil at any point. Summary deductions from the nature of the local rock, with this intent, are admittedly futile. It is rash to maintain, on the contrary, that agencies which have mingled the components of the Drift, and placed it where it lies, have obliterated all traces of its geological sources and connections.

---

* See references to the places referred to in Table, (pp. 41, 42).

† An incidental advantage is in many places made use of—one entirely due to the transportation of rock detritus. Deeply concealed limestone drift, cut through by streams, sheds its boulders along the water courses from steep banks continually undergoing erosion. These boulders form readily obtained supplies of limestone for burning, in regions sometimes very distant from limestone tracts.

Discrimination of Soils.

The boulders, small stones, pebbles, and discernible particles contained in the Drift, and equally in those more or less modified portions of it which are known to the agricultural reader as "soils," "earths," &c., being the undestroyed relics of disintegrated masses, which also yielded the intermingled clay and sand, are data from which the nature, quality, site, and other particulars respecting their geological sources, may be judged. By a careful discernment of the stony contents, therefore, a judgment may be arrived at, concerning the probable leading fertilizers which may be counted upon, just as if the soil were *directly derived*, that is, had lain undisturbed upon its immediate rock-source in the solid crust.

With a view to illustrate this mode of judging soils, and the nature of the information requisite in order that agriculturists should be placed intelligently in touch with the geology of the country, a series of soils, subsoils, &c., has been collected from different places and examined. The results are here presented in tabulated form.* The samples of earth were taken without any attempt at selection, one above the other, at the same point geographically, where more than one sample is referred to; the finer materials, sand and clay, are what passed through a sieve 1-16th inch mesh, when the samples were air-dried; the pebbles when washed and dried, were arranged under the headings given in the table, as indicated by numbers 1, 2, 3, 4, or 5, according to their comparative abundance; and the amount of carbonate of lime in the finer material is similarly indicated, according as the degree of effervescence with hydrochloric acid, manifested its comparative abundance or deficiency. The grouping of the different rock particles, set forth in the table, is based upon the prevailing minerals of agricultural importance, which the rocks represented in the particles usually contain.

Elements of Enrichment.

When it is considered that silicate of alumina (clay) in itself furnishes no essential element of plant food, and that its function, as regards food supplies, is to act as an absorbent of such mineral substances as are released by solvents from their complex and unavailable compounds, pending their appropriation by crops, it is evident that the stony particles, pebbles, &c., contain the stock supplies of mineral nutrients. This in itself shows that the agricultural enquirer may learn much regarding the endowments of his soil from its stony contents; also, that a moderate admixture of stony particles may be advantageous, especially if they are rich in fertilizing substances. The presence of a quantity of coarse gravel and pebbles in clay loam greatly increases percolation and facilitates cultivation.

---

* From a Paper read by J. R. Kilroe to the Royal Dublin Society, April 22, 1896. Published in 1897, with Drift Map.

Deterioration.

The great solubility of limestone, and, it may be added, of any calcareous matter in the form of carbonate, contained in grit, shale, and slate, accounts for the striking scarcity of carbonate of lime in the uppermost portion of limestone boulder clays* in many places—as may be seen in the table. It is rare when sufficient lime is not present to meet the requirement of plant fabrication; yet for the subsidiary and important requirements of soil amelioration, promotion of micro-organic life and functions, and, possibly, chemical reactions with compound silicates, towards the release of their alkalis, an ample supply of lime is a desideratum; and this, the top portion of limestone boulder-clay deposits may lack. Solution of carbonate of lime in soils has gone on for centuries, and is incessantly proceeding in our humid climate, which occasions no small loss of this and other valuable mineral substances.

For a more perfect appreciation of the circumstances of the Drift throughout the country—its nature and origin, the means of its transport, and the manner of its distribution and arrangement—as well as for an intelligent if not a complete estimate of the nature and distribution of non-transported soils, a somewhat detailed description of the geological Formations will be necessary. They are described in Chapters V. to IX., preceded in Chapter IV. by an outline of leading geological principles and explanations of terms for the sake of the general reader.

---

* An interesting circumstance was noticed by the writer in some recent examinations of calcareous boulder clays, namely, that while the *soils* effervesced with acid, showing the presence of carbonate of lime, the fine matter of the immediate subsoils was quite, or almost, devoid of that substance; while it again appeared, and gradually increased, downward, becoming very abundan at a depth of 2′ 6″. The humous acids formed through decay of organic substances in the soil, operate with greatest effect on the layer immediately underlying the soil; and with lessening effect downward, because of becoming gradually satisfied by the dissolved substances. This fact probably accounts for the circumstance that to mingle much of the subsoil with the soil does not always enrich it, the contrary being often the case. If material could be taken from a still deeper layer, the results would be better.

TABLE.

TABLE showing Nature of SOILS, SUBSOILS

ABBREVIATIONS.—L. = loam ; S. = subsoil ; D. = drift ; U. C. = Upper Boulder-clay ; L. C. = Lower Boulder-clay ; G. = gravel ; s. = sandy ; g. = gray ; y. = yellow ; r. = red ; b. = brown ; l. = light ; d. = dark ; 1, 2, 3, 4, 5 comparative abundance,—5 being maximum.

No.	Sample.	Subjacent rock.	Locality.	County.	Geological Inch Sheet.
1	y. b. L.,	—	Dunboyne,	Meath,	101
2	y. S.,	—	"	"	"
3	y. U. C.,	—	S. of Dunboyne.	"	111
4	d. g. L. C.,	Limestone,	"	"	"
5	y. U. C.,	—	Lucan,	Dublin,	"
6	d. g. L. C.,	Limestone,	"	"	"
7	b. s. L.,	—	Skerries,	"	102
8	b. S. (10 ft. below),	Limestone,	"	"	"
9	y. U. C.,	"	Sallins,	Kildare,	119
10	l. b. s. L.,	—	Cabra, Kells,	Meath,	90
11	y. g. U. C.,	Grit and slate,	"	"	"
12	b. U. C.,	—	Greystones,	Wicklow,	121
13	d. g. L. C.,	Grit and slate,	"	"	"
14	b. s. L.,	—	Grange Con,	"	129
15	S.,	—	"	"	"
16	L. C. (20 ft. below),	Grit and slate,	"	"	"
17	y. b. U. C.,	"	Glenealy,	"	130
18	Drift,	"	Rathdrum,	"	130
19	l. g. U. C.,	—	Kilsallagh,	Mayo,	74
20	d. g. L. C.,	Mica-schist,	"	"	"
21	y. s. U. C.,	—	Near Westport,	"	"
22	d. g. L. C.,	Limestone,	"	"	"
23	l. b. s. L.,	—	Near Newport,	"	"
24	y. s. U. C.,	—	"	"	"
25	d. g. L. C.,	Limestone,	"	"	"
26	y. U. C.,	—	S. of Castlebar,	—	75
27	b. U. C.,	—	W. of Kilboyne,	Mayo,	75
28	l. b. L. C.,	Limestone,	"	"	"
29	d. b. D. (surface),	"	At Kilboyne,	"	"
30	" "	"	Manulla,	"	"
31	s. D.,	O. R. S.,	W. of Castlebar,	"	"
32	y. U. C.,	Limestone,	Aghagad,	Roscommon,	87
33	y. U. C.,	"	"	"	"
34	L. C.,	"	"	"	"
35	y. b. U. C. = S.,	—	Castlecoote,	"	"
36	y. L. C.,	Limestone,	"	"	"
37	y. b. s. L.,	—	Bantry,	Cork,	199
38	y. U. C. = S.,	—	"	"	"
39	d. g. L. C.,	Grits and slate,	"	"	"
40	y. U. C.,	—	Derryvree,	Fermanagh,	45
41	d. b. g. L. C.,	Limestone,	"	"	"
42	r. b. D.,	"	1 mile S. of Lisbellaw,	"	"
43	y. U. C.	—	Omagh,	Tyrone.	33
44	d. g. L. C.,	Limestone,	"	"	"
45	r. D.,	O. R. S.,	¾ mile S. of Omagh,	"	"
46	y. b. U. C.,	—	Newbliss,	Monaghan,	58
47	d. g. L. C.,	Grits and slates,	"	"	"
48	g. D.,	Granite,	Baltinglass,	Wicklow.	129
49	s. D.,	Grits and slates,	Ballinhassig,	Cork,	194

and Boulder Clays in various places.

Contents.			Rock Fragments and Boulders.							
Percentage.		Comparative quantity of carbonate of lime.	Potash-Alumina-Silica Group.					Lime-Phosphate-Magnesia Group.		
Fine sand, clay, and humus.	Coarse sand and gravel.		Acid igneous rocks.	Felspathic grit.	Sandstone, grit, and quartzite.	Quartz & chert.	Shale, slate, and mica-schist.	Basic igneous rocks.	Limestone.	Calcareous grit and shale.
–	–	2	–	–	3	3	–	–	1	3
–	–	2	–	–	3	3	–	–	1	3
–	–	2	–	–	3	2	–	–	–	3
–	–	5	–	–	–	1	–	–	5	2
–	–	3	–	–	3	1	–	–	2	3
–	–	4	–	1	–	2	–	–	4	3
65	35	3	–	2	3	1	2	–	2	3
30	70	3	3	2	3	1	1	2	2	2
70	30	2	–	–	3	–	–	–	2	3
50	50	–	–	3	3	1	3	–	–	1
37	63	1	–	3	3	1	3	–	–	2
46·4	53·6	2	3	2	3	1	2	–	2	2
–	–	5	1	2	2	–	–	–	4	–
51	47	1	–	–	4	–	2	–	–	2
49	51	3	–	–	3	–	1	–	3	2
10·3	89·7	5	–	–	3	–	1	–	4	1
61	39	1	2	2	4	–	1	–	–	–
29	71	–	–	–	–	1	4	–	–	–
59	41	–	–	–	3	2	–	3	–	–
52	48	3	–	–	2	2	2	3	3	2
71	29	–	1	2	3	2	2	1	–	–
63	37	4	–	–	3	–	1	–	4	–
84	16	–	1	–	5	1	–	–	–	–
73·8	26·2	–	1	–	4	1	1	–	–	–
50	50	4	1	–	2	–	–	–	5	–
80	20	3	–	–	5	–	–	–	–	2
79	21	2	–	–	5	1	–	–	–	2
57	43	5	–	–	2	1	1	–	5	–
58·8	41·2	5	–	–	1	1	–	–	5	–
46	54	5	–	–	–	1	–	–	5	–
58	42	1	1	3	4	1	–	–	–	–
56·5	43·5	1	–	–	4	1	–	–	–	3
71	29	3	–	–	4	–	–	–	3	–
–	–	5	–	–	1	–	–	–	5	–
75	25	1	–	–	3	2	–	–	1	–
50	50	5	–	–	2	1	–	–	5	–
64	36	2	–	1	3	–	2	–	1	1
73	27	1	–	–	3	–	2	–	–	1
50	50	4	–	–	2	1	3	–	4	2
93	7	1	–	–	4	1	–	–	1	–
71	29	4	1	–	3	1	1	–	3	–
60	40	3	–	–	3	1	1	–	3	–
62	38	1	–	2	3	1	2	–	–	–
37	63	5	1	–	–	1	1	–	4	2
49	51	2	–	–	4	1	1	–	–	–
–	–	3	–	–	4	1	–	–	2	–
47	53	4	–	2	3	1	1	–	3	–
68	32	1	3	–	3	1	2	2	2	–
29	71	–	–	–	5	–	2	–	–	–

SECTION II.

THE GEOLOGICAL FORMATIONS FROM AN AGRICULTURAL POINT OF VIEW.

CHAPTER IV.

NATURE AND ORDER OF THE FORMATIONS.

By the term *Formation* the reader will understand a set of strata which, except where highly metamorphosed, are characterized by certain life forms, now fossil. These existed and became entombed in successive periods of the world's history during which the strata in question were being formed—in every case probably incalculably remote. By means of these ancient life-forms, corresponding groups of rocks may be identified in regions as far apart as the antipodes, even though the rocks display a great diversity of lithological character. The name given to each Formation originated in the necessity for recognizing some prominent feature therein, a fact connected with it, by means of which it could readily be identified. Thus, the *Carboniferous* Formation contains important *coal* deposits; the *Cambrian* Formation is characteristically developed in *Wales* and was first studied there in detail, and so-forth. Some of the Formations are not found in Ireland, nor, indeed, are all that are known fully represented in Britain. A great array, however, occurs there, the oldest being met with in the northern half of Scotland and in Wales, and the newest in the south-east corner of England. These are set forth in descending order in the following table; and it will best suit our present purpose, while noting the Formations, &c., which are absent from this country, to place side by side with the others, a description of the rocks which represent them in the Irish area. The naming of the groups of strata in Ireland corresponds with that adopted in Britain, as set forth in the Table on the following page.

Stratification.

For an explanation of the relations between the different Formations, the reader's attention is invited to the disposition of strata represented in a few selected geological views and sections, preliminary to

TABLE OF FORMATIONS.

Age.	British Formation.		Corresponding Irish Strata.
TERTIARY OR CAINOZOIC.	Post Pliocene,		Drift deposits.
	Pliocene,		Doubtful.
	Miocene,		(?) Absent.
	Eocene,		Basaltic sheets of north-east Ireland (with intervening iron-ore and leaf beds) and trachyte.
SECONDARY OR MESOZOIC.	Upper Cretaceous,		White limestone ("Chalk") of Antrim and Londonderry.
	Lower ,, (Neocomian),		Absent.
	Jurassic, including :—		
	Oolitic Group, containing important sub-divisions.		
	Lias,	Upper,	
		Middle,	
		Lower,	Bluish, light and dark gray clays and earthy limestone.
		Rhætic,	Dark shales and light greenish calcareous sandstone.
	Trias,	Keuper Marls,	Red marls, with gypsum and "rock salt" N. of Belfast Lough.
		Bunter Sandstone,	Red sandstone ("New Red Sandstone") Lagan Valley, and N. and S. of Belfast Lough.
PRIMARY OR PALÆOZOIC.	Permian Beds,		"Magnesian limestone," with sandstone near Cookstown and with marl near Cultra. Red breccia at Armagh.
	Carboniferous,	Coal Measures,	Sandstone and shale series, with coal seams in the uppermost strata.
		Millstone Grit,	
		Yoredale Beds,	
		Limestone,	Limestone (including Upper, Middle, and Lower Limestone), with shale and sandstone beds.
		Lower Shales and Sandstone,	Sandstone and shale beds, grit and slate.
	Old Red Sandstone,	Upper,	Red, green, and chocolate-coloured sandstone, shale, and conglomerates.
		Lower,	
	Silurian Group,	Upper,	Greenish and bluish gray, hard, grits and quartzite, with shale, slate, and mica-schist, and limestone beds.
		Lower,	
	Cambrian,		
	Metamorphic Rocks (of North Britain).		Mica-schist, quartzite, limestone, &c., of Donegal, Mayo, and Galway.

which it may be well to point out that sedimentary rocks, whatever the Formation to which they belong, were originally deposited on the floors of ancient oceans, seas, rivers, lakes, or deserts; just as sediments are laid down at the present time—whether as river-silt, clay, and mud, carried out to sea, and distributed far and wide over the ocean bed, or as beach shingle and sand formed in proximity to land, and spread outward by waves and currents; or as calcareous and siliceous mud-ooze, formed in ocean depths, and consisting almost wholly of microscopic animal life and remains; or as coral rock (limestone), the secreted product of the coral polyp, and calcareous sand, the comminuted portions of reefs broken off and *triturated* by ocean waves and surf. The natural position of strata thus formed is, and would remain, horizontal, but for disturbances which will presently be explained; and a series of beds might attain hundreds, perhaps thousands, of feet in thickness in a gradually subsiding area of the crust. The cliffs of Moher, on the Clare coast, which may be referred to as an illustrative instance, present to view hundreds of feet in thickness of limestone strata, piled up bed over bed, as shown in the accompanying woodcut (Fig. 5)* :—

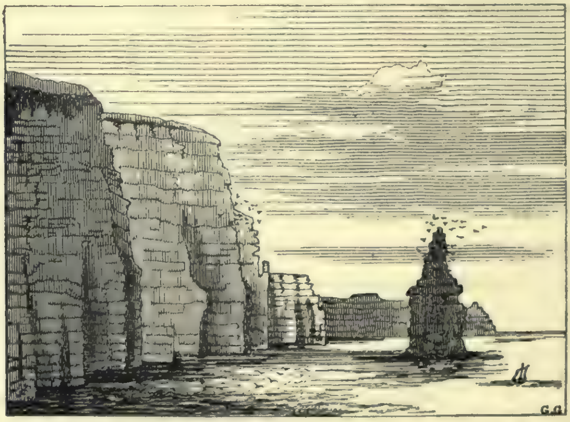


Fig. 5. The Cliffs of Moher, showing horizontal stratification.

Marine Denudation.

We are enabled to view rocks formed on an ancient sea floor, by their elevation above the ocean surface; and to what an extent this elevation may take place, may be judged from the fact that rocks formed in the ocean depths, as above described, now form the highest mountain chains on the surface of the globe. During emergence, and possibly submergence and re-emergence frequently repeated, marine denudation has shorn off great slices from the uplifted strata; and atmospheric waste, with stream and river denudation, has further modified the land surfaces so formed. Hills and valleys are sculptured by these latter agencies; they are the results of the unequal removal of stratified and non-stratified rocks, a simple instance of which is given in the following section across Knocknashee (Fig. 6).*

---

* Taken from Explanation of Sheets 114, 122, 123, p. 6.

The reader will observe that the strata in this section are not horizontal; they are inclined to the horizontal at a certain angle, which is technically known as *dip*. It is the inclination of the line of steepest descent upon a bed or stratum of rock, as referred to the horizontal; and is found by means of a simple instrument called a *clinometer.* Sections are usually drawn in the direction of the line of steepest descent; and if they are true to scale—both horizontal and vertical—the inclination of lines in the section corresponds exactly to the dip of the rocks in the field. The direction at right angles to that of dip, is the *strike* of the strata; and their *outcrops* run in the direction of strike. By drawing a section to scale through any required point, from the outcrop of any particular bed (Coal - seam, iron-stone band, bed of rock-salt, &c.), with the dip line at the proper inclination, the depth of the bed below the given point may be ascertained—if the surface be horizontal. Otherwise the height of the point above, or its depth below, the horizontal must be added or subtracted.

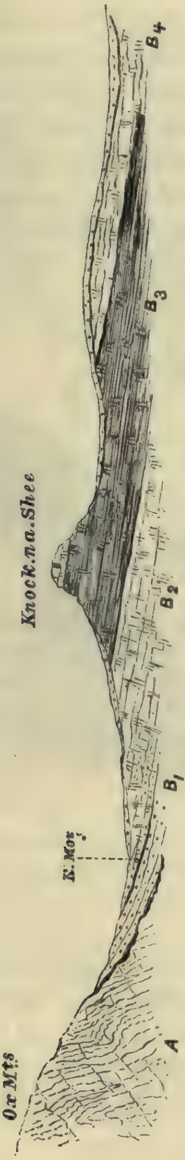


Fig. 6. Section through Knocknashee, normal to the escarpment; showing succession of Carboniferous Rocks from Mica Schist (A) upward; Lower Carboniferous Sandstone (B_1), Arenaceous Limestone and Lower Limestone (B_2), Calp (B_3), and Upper Limestone, with its outlier capping the hill (B_4). The dotted strip which covers the edges of the Limestone and Calp beds, represents superficial deposits, viz., Drifts, &c.

---

* Taken from Explanation of Sheets 42, 54, p. 11.

Disturbance and Crumpling.

The cosmical forces which produce upheaval, such as was above referred to, may be attended with a gentle inclination of the strata, or may have been so violent in effect as to set the beds of rock "on end," standing vertically or nearly so, as may be seen in the districts referred to in the following woodcuts and view. The earth stresses may be so excessive as to crumple up the strata, and produce cleavage therein. This is well shown in the accompanying diagram of beds of limestone near Mitchelstown in Cork (Fig. 7).* Cleavage has already been explained as the structure of slate: such structure is unusual in limestone though inhabitants of parts of Cork are familiar with it.

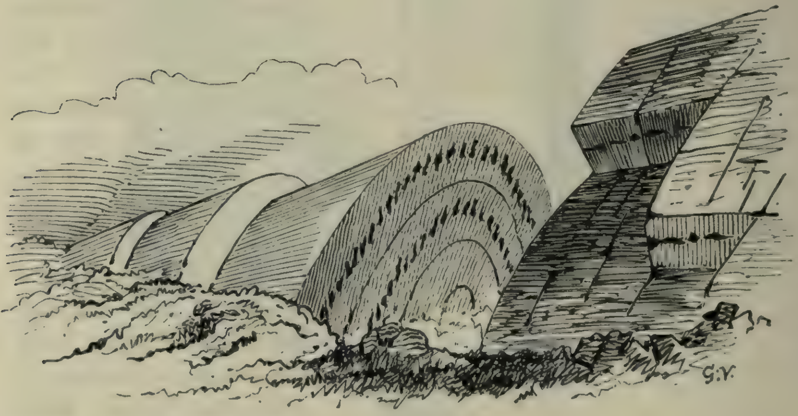


Fig. 7. Diagrammatic Sketch. Cleavage in Limestone, re-arranging chert nodules. On road, S.W. corner of Mitchelstown Castle Demesne, Co. Cork.

The compression of rocks may be so great as to produce *metamorphism*—a partially crystallized form as explained in Chap. II.; and the reader is reminded that the effects here reviewed, all seem to have been brought about when the rocks were deeply seated in the crust. Those now visible at the surface have been exposed to view through subsequent denudation.

---

* Taken from Explanation of Sheet 165, p. 21.

A view of limestone beds, at Beauparc in Co. Meath,* exhibits irregular contortions—taken up, the reader may be reminded, when the rock possessed its ordinary molecular structure, it was *solid*, except as under extreme pressure: (Fig. 8).

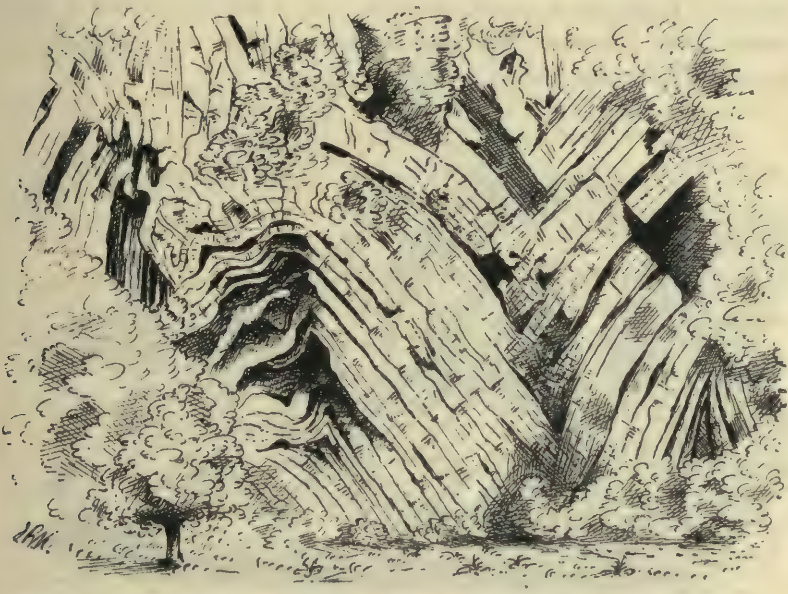


Fig. 8. Sketched from photograph of contorted limestone beds, at Beauparc, Co. Meath, shown at page 2, "Ireland: Industrial and Agricultural."

Such distortions of the strata as are above instanced are attributable to shrinking of the earth's interior through secular cooling, which produces wrinkling of the crust. The wrinkling has taken place at different epochs of the earth's history, and along certain zones or axes, the directions of which are now marked by mountain chains and other less palpable superficial phenomena. Amongst these are crumpling, anticlinal and synclinal foldings, and overthrusting, in which strata on one side of a line of dislocation have been pressed against, and sometimes *over*, adjoining strata. Some four such systems of axes have been recognized in the European area, two of which at least are manifest in Ireland. One of these, known as the *Caledonian* system, accounts for the north-western, and the Leinster mountain-chains. This system belongs to the Old Red Sandstone Period, and as determining the general north-eastern trend of the mountain chains may be said to have initiated the shape of the island. The second great system of crumpling, known as the *Hercynian*, took place subsequently to the Carboniferous Period, and accounts for the trend of the mountain ridges of the south, and for the present southern outline of Ireland. Foldings belonging to this system are recognizable as far north as Meath, where the trend of the axes is north easterly, while it is a little north of east in the south.

After rocks have undergone upheaval and denudation, the upturned and denuded edges may, consequent upon resubmergence, become the base of a new series or Formation. Such a break in the succession of beds is known as an unconformability, and is well represented in the sketch (Fig. 9)* where Old Red Sandstone strata rest discordantly upon "Dingle Beds."

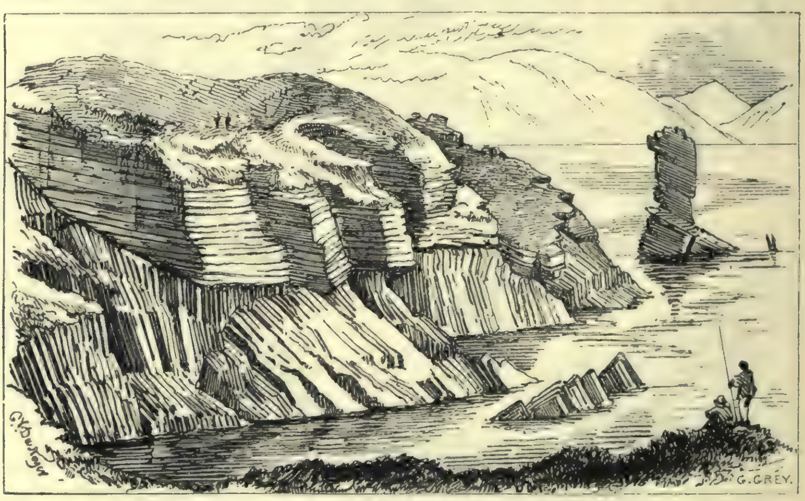


Fig. 9. Bull's Head, looking S.E., showing the Old Red Sandstone resting unconformably on the Dingle beds.

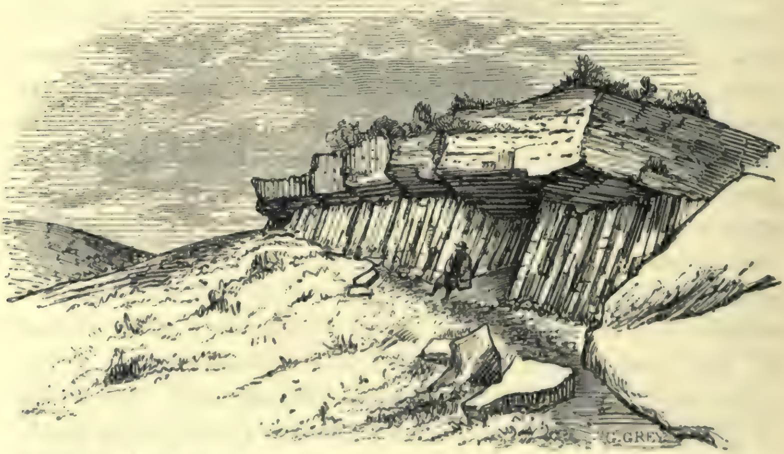


Fig. 10†. Old Red Sandstone resting unconformably on the Silurian slates and grits, N.W. of Altoir Ultach, near Feakle, Co. Clare.

---

* Taken from Explanation of Sheets 160 and 172, p. 33.

† Taken from Explanation of Sheets 124, 125, p. 25.

A similar disposition of strata is set forth in section in Fig. 10 where these rest upon upturned Silurian beds. It will be understood that the upward continuation of the latter beds has been removed by denudation prior to the Old Red period.

Such facts represented in section are as given in Fig. 11.*

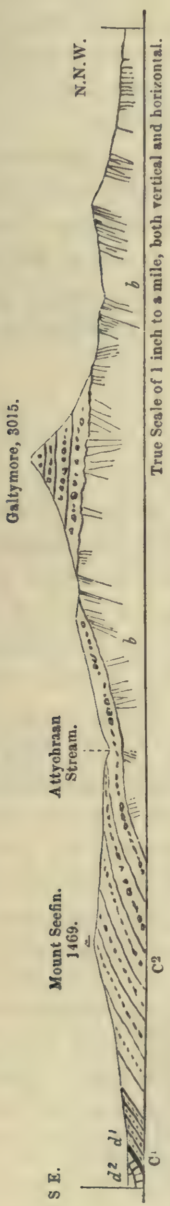


Fig. 11. Section from Mitchelstown Valley across Galtymore to the Vale of Agherlow, showing Old Red Sandstone C² resting unconformably upon Silurian Strata (*b*), and underlying Carboniferous Shale *d*¹ and Limestone *d*².

By means of the data illustrated in these figures it is possible to trace the geological episodes which have occurred in the distant past, over the portion of the earth's crust now forming the south of Ireland.

Briefly presented they are as follows, viz. :—

First.—Deposition of Silurian strata and Dingle Beds.

Second.—The compression and sharp-folding of the strata thus formed, accompanied probably by their elevation above the ocean surface.

Third.—Denudation by sub-aërial, and to some extent also marine agencies, which removed portions of the strata, leaving the remaining portions standing at high angles.

Fourth.—Deposition of Old Red Sandstone strata, it is believed, in great fresh-water lakes.

Fifth.—Gradual lowering of the land with an encroachment of ocean water, and the deposition of Carboniferous strata under marine conditions.

Sixth.—Second period of compression, with folding and dislocation of strata.

Seventh.—Elevation above the sea-level and denudation.

The conditions of stratification here presented, usually mark a change from an older to a newer Formation, and are accompanied by a change of fossil forms.

---

* Taken from Explanation of Sheet 165, p. 4.

Generic Peculiarities.

Well-marked peculiarities of a generic kind characterise the rocks belonging to each Formation in the Irish area, a fact which will not appear extraordinary when the manner of their formation is borne in mind, as well as the small area this island covers, say, on a map of Europe; when compared with the vast areas over which Formations are distributed and recognisable by means of their fossils, and the oceanic areas in which new Formations are now being laid down.

A lithological description of each Formation is therefore fairly reliable, as a ready means of identifying it—lacking fossil evidence, which is not always easily procurable; and, though diversity of character in the rocks may appear within the compass of any series, the identification of the varieties, and the order in which they occur, is possible, even in districts far apart, and renders the general resemblance in the aggregate all the more striking.

The Pristine Crust.

From what has been presented, the reader will perceive that each successive Formation consists of reassorted materials (shingle, sand, mud, clay, &c.) derived from those which preceded it; and if we allow our minds to travel backward, from stage to stage of the vast record, we arrive at a point when no sedimentary rocks were in existence, and when the crust of the earth probably consisted of a solidified once-fluid magma, resembling, in composition at least, known igneous rocks. From such an origin, obviously, all other rocks have directly or indirectly been formed.* It is doubtful whether the original crust now appears at any point of the surface. It has sometimes been supposed that granite or granitoid rock—because of underlying the rocks of a district—in Wicklow, for example, is the oldest kind of rock known. This is an erroneous view. Granite may, indeed, be amongst the newest rocks in a district. This may be judged from such a sketch as the following (Fig. 12),[*] where the granite is seen to penetrate the adjoining and therefore older rocks.

---

* Except those of organic (vegetable) origin. If the reasonable hypothesis be accepted that this globe was once a molten mass, the presence of water upon its surface, and therefore, the existence of aqueous rocks, would have been an impossibility until the earth had cooled down to a temperature approaching 212° F. At the temperature of molten rock, carbonates could not have existed at the surface, nor could any known combinations of nitrogen. The vast quantities of carbonic acid pent up in limestone and other carbonates, and represented in other combinations of carbon in the great aggregate thickness of coal seams, lignite, peat, and graphite; and the quantities of nitrogen stored up in the carbonaceous deposits just named, as well as in the nitrate beds of Chili and elsewhere, must therefore have come originally from the atmosphere.

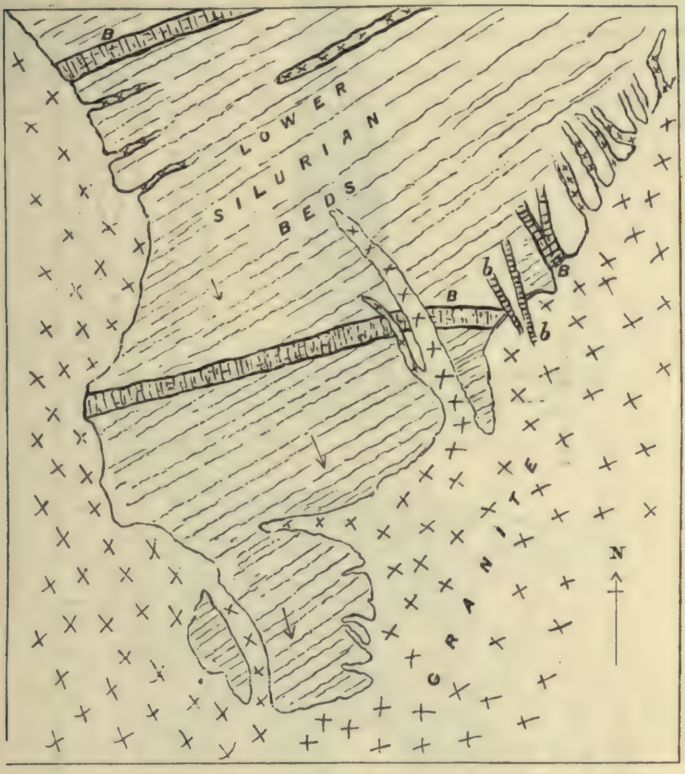


Fig. 12. Plan of portion of Pigeon Rock Mountain showing Silurian Beds capping granite—and dykes of the "Older Basalt" (B.B.) terminated at the granite margin—while both rocks are traversed by more recent dykes (*b.b.*)—Plan taken from the 6-inch geological field-map of Co. Down.

Igneous rocks may present great complexity in mode of occurrence, as well as great variation of character, and that within small areas. This is chiefly due to the fact that plutonic forces, having discovered a region of weakness in the crust, are liable to seek relief there, recurrently from time to time, accompanied probably by volcanic action. In the region of Carlingford, evidence is found for such recurrent activity, as may be observed in the complexity presented in the section across Barnavave Hill, here given (Fig. 13).[†] The Gabbro had first been intruded into sedimentary rocks. It, in turn, was invaded by rock of quite a different character—an acid igneous rock; and then dykes of basalt probably of later date subsequently invaded the region.

[*] Taken from Explanation of Sheets 60, 61, 71, p. 16.

[†] From Explanation of Sheets 60, 71, p. 44.

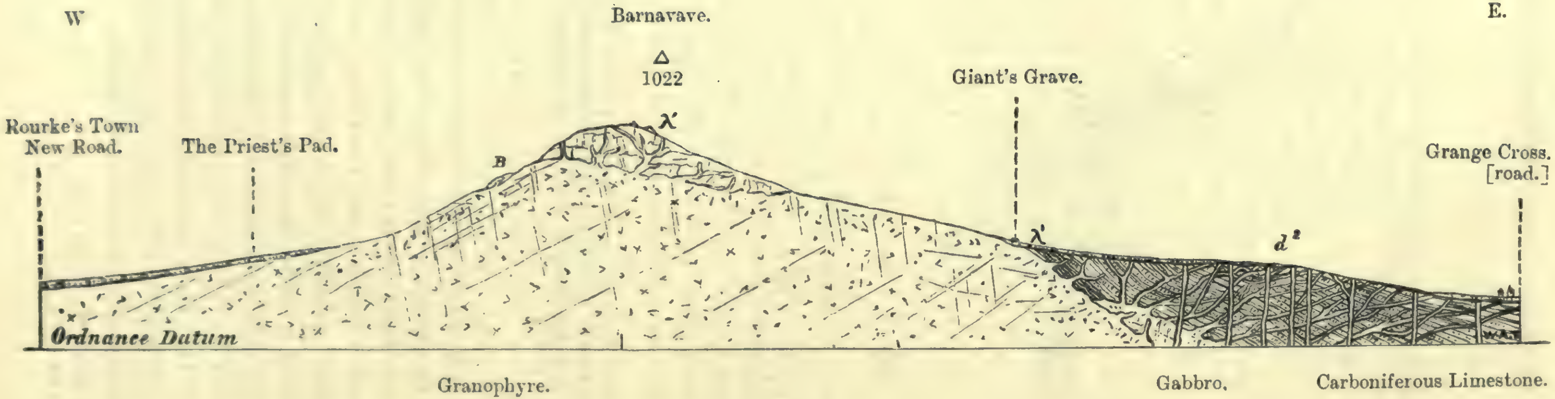
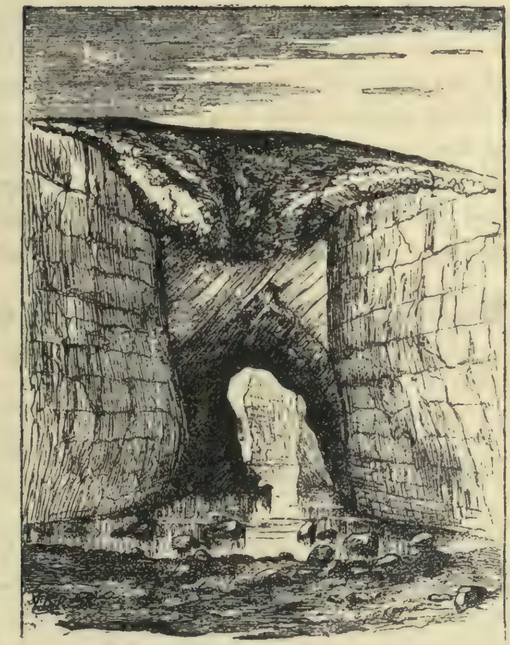


Fig. 13. Section across the southern end of Barnavave Mountain. From W. to E. Length, 1^1 miles. On natural scale, 6 inches to 1 mile. d^2=Carboniferous Limestone, with trap dykes, counterpart of the Commons' Quarry. λ^1 Outlier of Carboniferous Limestone, metamorphosed. B = Outlier of Gabbro.

The scarcely distinguishable "outliers," on the summit, are portions of the limestone series which is seen in the eastern part of the section, and formerly occupied the place now filled by a granite rock (granophyre). The limestone indeed extended far to the west, not shown in the section. The series was first invaded by gabbro, which sent numerous dykes through the limestone, and which also had a wide extension westward, as may be judged from the occurrence of outliers at and near the summit of the hill. It, in turn, was invaved by granophyre, which now almost wholly forms the hill; a set of basalt dykes seen in the eastern part of the section also penetrated the gabbro, as well as the limestone. Denudation has since supervened, has carved out the natural features, and made it possible for the observer to trace the episodes.

Dykes of igneous rock, it may be mentioned, are portions of once molten material, which were injected from below into fissures in the crust. Some such dykes stand out in relief above the more readily weathered surfaces of the containing rock ; while hollows, in other regions where the containing rock is more difficult of disintegration, may also mark the courses of the dykes. This latter is the case in the granite tract of Donegal, where the positions of numerous basalt dykes are indicated by streaks of vegetation traversing regions of bare rock-surface.



Cave, north end of Cruit, N. coast of Donegal.
Formed by the partial removal of a dyke of felsite between granite walls.*

From Explanation of Sheets 3, 4, 5, &c., p. 85.

CHAPTER V.

METAMORPHIC ROCKS.

The Formations will now be described, in regard to their geographical distribution, disintegration, soil-characters, and physical features. The distribution at first sight may seem promiscuous, independent of the operation of any law, but it is not really so. It is the outcome of relations subsisting between the Formations—their order of succession and superposition, as sketched in the preceding chapter, conjointly with upheavals of the crust, and various degrees in which the rocks have yielded to denudation—all determined by fixed geological principles, well known to science. There are definite reasons why certain rock groups or Formations should form elevated ground; why others should occupy relatively low-lying tracts; why Silurian rocks should be margined in certain places by Old Red Sandstone, and elsewhere by Carboniferous strata. A full discussion of those principles finds appropriate place in text-books of the science; here it must suffice merely to allude to principles and laws, giving special attention to the distribution of Formations in Ireland. We commence with a group of highly altered igneous and sedimentary rocks, known as *Metamorphic*, these being generally regarded as the oldest in the country.

Gneiss, Mica-Schist, Hornblende-Schist, Quartzite, Limestone.—These rocks, as their title signifies, are such as have undergone *change of form*. Gneisses are modifications of granites and allied rocks: and hornblende-schists are also modified forms of igneous rocks. The alteration in character probably took place as already stated, in deep-seated portions of the earth's crust, and the overlying strata, which concealed the altered rocks, have since been removed by denudation. The metamorphic rocks of this country lie chiefly in the Counties of Donegal, Londonderry, Tyrone, Mayo, and Galway; extend into the northern part of Fermanagh; appear in the north-east of Antrim; and form fringes around the granites of Down and Leinster.

The larger tracts are in general mountainous, and are cut by deep valleys, which is in accord with the indented coast line visible where, as in Donegal, Mayo, and Galway, metamorphic rocks reach the seaboard. The indentations are but recent instances of ocean encroachment upon formerly existing valleys; and an inspection of a geological map will show that tracts of more recent strata, of Old Red Sandstone, and Carboniferous periods, in proximity to Metamorphic rocks, are now skirted on the land side by high grounds which probably formed the margins of ancient bays. Thus the area of Carboniferous strata around Donegal Bay presents a striking exhibition of such ancient geographical conditions; those around Killala Bay also; and a tongue of the newer strata separates the metamorphic rocks of North and South Mayo; in other words, the newer strata conceal the continuation of the metamorphic rocks of the two regions, beneath.

The schists, quartzites, &c., of North Mayo, Donegal, and adjoining counties are the counter-parts in character of, and probably were formed contemporaneously with, the metamorphic rocks of Connemara. Recent revision of these tracts has resulted in the discovery, that a definite grouping of the different types of rock obtains in all those areas; and that the original order of succession of the strata is as given below, though sometimes the order may have become inverted through stupendous movements of the earth's crust, accompanied by the overfolding of the different stratigraphical groups.

1. Quartzite, with subsidiary bands of mica-schist and conglomerate; over

2. Limestone, occasionally wanting, with associated pebbly bands and boulder beds.

3. Mica-schist, with subsidiary bands of quartzite, crushed pebbly grits, and black slate, hornblende and sericitic schists, and phyllites.

Gneiss, Mica-schist.—Gneiss may be described with mica-schist; for, though differing in origin, they resemble each other in structure, both split with comparative ease along certain mineralized planes—planes of *foliation*. In composition, too, mica-schist may resemble gneiss in containing quartz, felspar, and white or dark green mica. Gneiss, however, usually contains a much larger quantity of felspar than mica-schist, and is in consequence capable of supplying more potash to derived soils. With regard to this consideration the reader is referred to the chapter devoted to granite and other igneous rocks.

An inconsiderable tract of gneiss extends from Ballyshannon, north-eastward, towards Lough Derg in Donegal, and a similar tract lies to the north of Pomeroy, in Tyrone. Both these areas present conditions uninviting to the agriculturist, the prevailing aspect of each being hummocks of bare rock, with intervening peaty patches, clay-soil being scarce, and of poor quality. Other small tracts of gneiss occur in North-west Mayo and South-east Wexford.

The principal area of mica-schist extends from Londonderry, south-westward, through Donegal. The same rock forms a large portion of the Ox Mountains, in Leitrim, Sligo, and Mayo, spreads out into a wide area to the west of Nephin, in North Mayo, and occupies most of the low grounds in Connemara, about Clifden and Maam.

Exceptionally Fertile Areas.

A great tract of the mica-schist ground in Londonderry and Tyrone, and a large proportion of it in Donegal, are practically waste. The Sperrin Mountains and Mullaghcarn group of hills are included in the former tract. Much arable land, however, well suited for tillage, is found over mica-schist in the baronies of Terkeeran and Strabane, in Londonderry and Tyrone respectively; and in those of Raphoe and Inishowen, in Donegal.

Patches of good soil over this rock occur near the West Coast in Donegal, at Dunfanaghy, Lettermacaward, Dawros, Glenties, Glencolumbkille, Malinmore, and Carrick, though in several of these places the verdure is due to limestone associated with the mica-schist.

A small area of the same rock in the north-east of Antrim is covered with favourable soil, but consisting, as it does, for the most part of transported materials (Drift), its character is but little dependent upon the nature of the underlying rock.

The mica-schist ground in Mayo and Connemara is for the most part covered with peat, and is otherwise unfavourably circumstanced for profitable agricultural treatment.

The zones of schist bordering the granites of Down, Armagh, and Leinster afford soils which contrast favourably with the less fertile detritus yielded by the neighbouring granite, while they resemble those derived from the slates and grits which bound the zones on the outside. The contrast mentioned is occasionally very noticeable in the cases of superficial patches of schist, included in, *i.e.*, surrounded by, the granite. as may be observed where such patches of mica-schist occur in the granite of Donegal.

This contrast in fertility seems altogether due to the more favourable root-hold for plants afforded by disintegrated mica-schist, than by disintegrated granite, for the latter is richer in plant-food than the former, except where mica-schist becomes calcareous—as in proximity to limestone lands, and occasionally elsewhere. Such mica-schist is to be seen in many places in Donegal, Tyrone, Mayo, and Connemara ; but the areas are unfortunately insignificant.

Disintegration of Mica-Schist.

Mica-schist is usually made up of white (or potash) mica, or "black" (or iron-magnesian) mica, and quartz. It frequently contains potash, or soda-lime felspars. The felspars are the first components perceptibly attacked, giving up their potash, soda, or lime to percolating waters, acidulated in the atmosphere and *humus*-charged soils, leaving clay. The micas disintegrate more slowly, but ultimately yield up their potash, iron, and magnesia. The resulting soil contains the remaining mineral quartz as sand, mingled with undecomposed mica flakes, which, with the sand, favour percolation, and such of the dissolved mineral substances as this soil is capable of retaining, or abstracting from the solutions, before these nutrient-charged waters ultimately escape. The soil is free-working, but naturally poor in, or devoid of, the ingredients which conduce to fertility. Without thorough manurings Risler speaks of it as suited to little else than the growth of oats, rye, buckwheat, and potatoes.

Analyses of mica-schist which, while not ignoring the favourable variations above mentioned, may be considered sufficiently typical for our purpose, exhibit the poverty of this rock in plant-food; one is here given, and one of gneiss. An analysis by M. Grandeau of subsoil derived from schist at Saint Michael, Department of Aisne, in France, is also added from *Géologie Agricole* (Vol. I., p. 163). The first and second are from Dr. Fream's book, "Soils and their Properties" (p. 18).

ANALYSES of METAMORPHIC ROCKS and DERIVED SUBSOILS.

Chemical Constituents.	Gneiss (Hartz).	Mica-schist (Pyrenees.)	Subsoil derived from Schists.
Lime,	3·27	0·28	—
Magnesia,	2·06	traces.	0·20
Potash,	2·74	2·48	0·17
Soda,	8·03	·59	—
Phosphor. Acid,	—	—	0·16
Iron Peroxide,	—	1·10	4·89
„ Protoxide,	1·00	3·61	
Alumina,	16·35	20·03	
Silica,	65·22	71·26	—
Residue insoluble in Acids,	—	—	88·00
Matières combustibles,	—	—	3·85
Water,	2·25	1·63	3·85
Totals,	100·92	100·98	101·12

Hornblende-Schist, which here and there occurs as bands and irregular masses in mica-schist, is comparatively rich in plant food, containing considerable proportions of lime and phosphoric acid, though it is not as rich in potash as gneiss or some mica-schists. It resembles these metamorphic rocks in structure, splitting with more or less ease along parallel planes, but otherwise, *e.g.*, as regards composition, soils yielded, and so forth, it closely resembles diorite, which is described later on.

The structure of these rocks, gneisses and schists, is such that the form of the ground resulting from their disintegration does not readily lend itself to successful irrigation, even were the drainage waters, flowing off the rocks or subsoils, so rich in fertilizing substances as to warrant the expense of utilizing it. The contour as a rule is varied, and often intricate. Knolls and gullies frequently occur, except where there are thick superficial deposits, and interrupt the evenly-flowing surface-curves which might otherwise be looked for on sloping ground. Drainage-water from the limestone bands met with in the schists would be valuable as a source of plant food for the poor soils adjoining the lime zones ; but here the difficulty presents itself, that the bands referred to almost uniformly occupy the lowest superficial levels.

Limestone, Marble.—Limestone is to be met with in many places in the metamorphic regions. It forms bands of greater or less thickness —the out-crops of beds, or of groups of beds, contained in these altered rocks. The limestone itself has undergone metamorphism, with the associated rocks, and is now crystalline, rather than finely granular and compact, such as probably it originally was. In colour it may be white, bluish, gray, greenish, pink or black. The white variety constitutes "marble," which may be finely crystalline, "saccharoid" ; it has been quarried for ornamental purposes in several places : a large quarry locally celebrated, but now worked out, at Dunlewy in Donegal, testifies to the extent to which this beautiful rock was once utilized.

The green marbles of Ballinahinch and Clifden in Connemara, consist of serpentine, or ophicalcite—a product of peculiar metamorphic action upon limestone bands there adjoining, and in parts penetrated by acid and basic igneous rock. Serpentine may also be a product of metamorphism, after basic igneous rocks, as in the case of a wide irregular band which skirts the Croagh-Patrick range on the north.

The localities where the limestone bands occur in metamorphic regions are generally to be recognized by spots and streaks of unusual verdure. Such desirable veins of land usually occur in low ground and hollows— these being formed by the more rapid solution and disintegration of the underlying limestone.

Out-crops of Limestone Bands.

The bands of this rock vary in thickness, and probably do not exceed 100 feet. When set on edge, as they often are found to be, their *out-crops* about correspond in width to their thickness. When, however the dip of the strata is low, and the beds lie almost horizontally, a small thickness of limestone may spread out so as to cover a wide area, as is the case at Killygordon and near Falcarragh in Donegal; and crumpling of the strata may also tend to give a wider outcrop, and thus a more considerable area of this important soil-forming rock, than could otherwise be expected. Such crumpling and fictitious thickening of strata is common amongst metamorphic rocks.

The crystalline texture of metamorphic limestone seems to render its calcination (burning) more difficult than that of Carboniferous limestone. Hence the latter is preferred for lime-burning when both are available. The crystalline limestone moreover, occurring as it does in comparatively thin beds, and having been formed originally in an ocean usually accessible to sediments, is liable to contain impurities, and is therefore less profitable as a source of lime, than the massive limestone of the Carboniferous Formation. Through the increase of such impurities the limestone bands are found to graduate into calcareous mica-schist on the one hand, or into calcareous quartzite on the other, according as the impurity may have been argillaceous or arenaceous, *i.e.*, clay or sand.

Crystalline as well as non-crystalline limestone consists almost wholly of carbonate of lime. It also contains magnesia, in greater or less proportion, oxides of iron, alumina, and occasionally manganese as well as small quantities of phosphoric acid. The value of lime, obtained by calcination (burning) of marble, as well as other forms of limestone, both as a plant food and as an ameliorative of heavy clays and peaty soils, has been already pointed out.

Quartzite.—This rock is the least valuable of all known types, as a source of soils. Except when it contains as accessory components carbonate of lime, felspar, or mica, it is quite devoid of fertilizing elements, and on weathering can only yield incoherent silicious sand. The usual aspects and the positions which this member of the metamorphic group usually occupies, superficially presented by its physical features, contribute in placing it outside the range of agricultural utility. Thus, it forms some of the highest hills in the country, with sharp summits and steep declivities. In Donegal, the Errigal and Muckish range consists essentially of quartzite—the range presenting four sharp peaks when looked at from certain points of view

Other ranges, consisting chiefly of quartzite, run north-eastward through Donegal from Glencolumbkille to Inishowen, the most striking features of which are Slieve League and Slieve Tooey in the south-west, Aghla in the centre, and Knock Salt near Mulroy Bay. In Connaught the highest and most striking hills are formed of this rock—the Nephin and Achil groups in Mayo, and the Twelve Pins and Maamturk

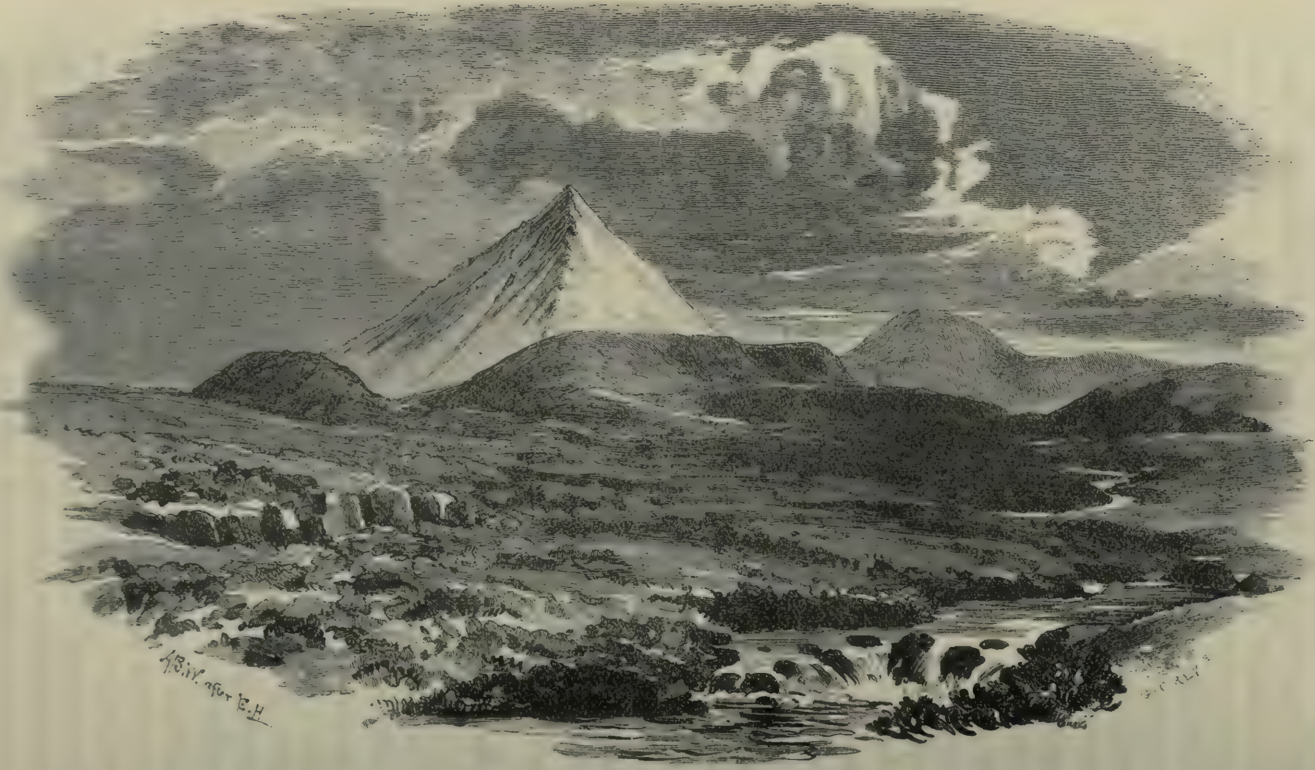

H.B.W. after E.H.

Fig 14. View of Errigal from the North.
Quartzite pyramid rising from a platform of diorite, schist, and limestone. In the distance to the right are the granite hills above the Poisoned Glen, Co. Donegal.

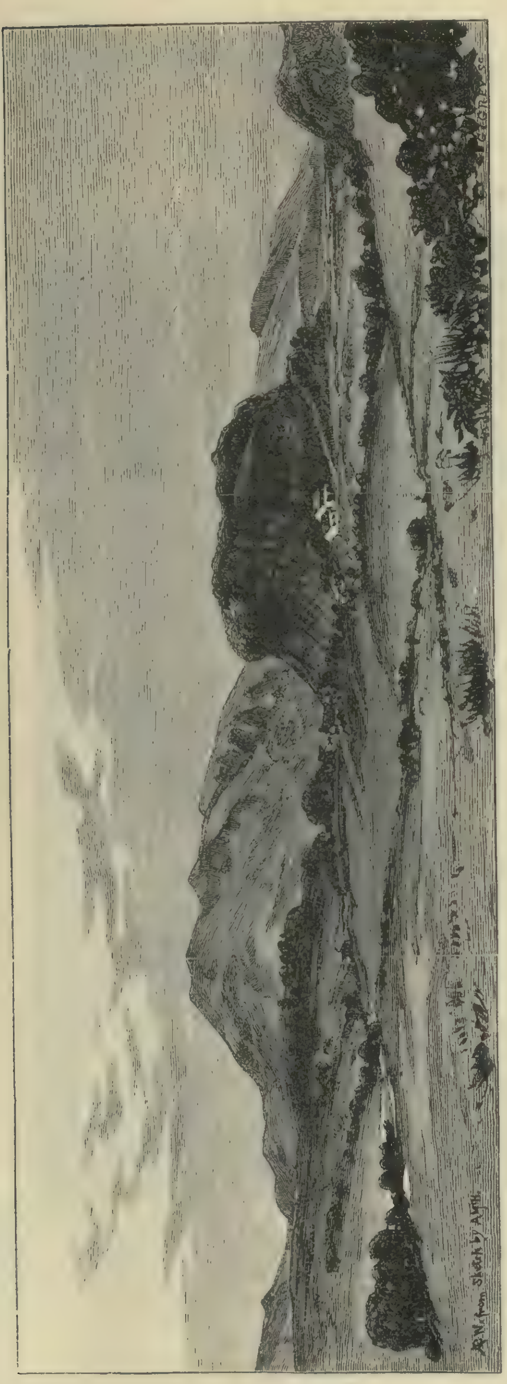


Fig. 15. Doon Rock (old volcanic neck), looking N.E., Lough Salt mountains in the distance.

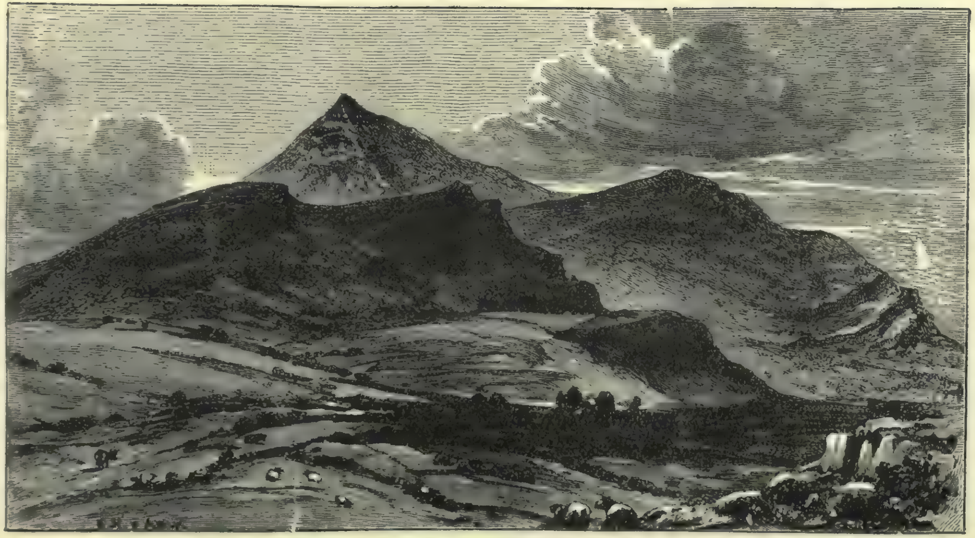


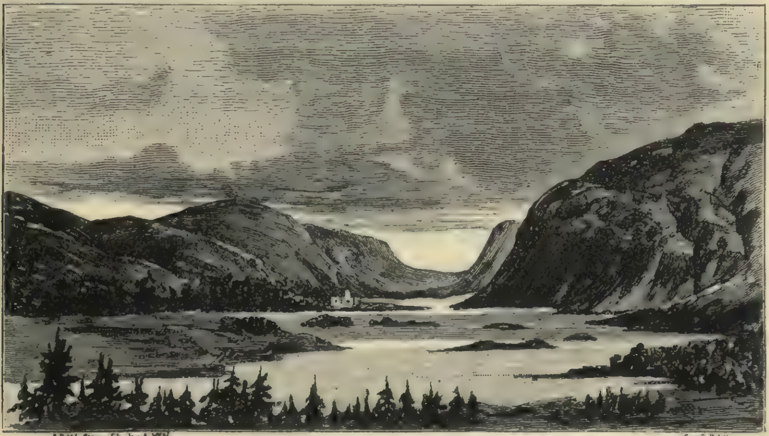
Fig. 16. Muckish Mountain from near Ards.

mountains in Connemara. Croagh Patrick in Mayo, and the Sugarloaf mountain in Wicklow, may also here be mentioned, though these hills will be described in the following chapter in their true geological connection.

The scenery formed by the Metamorphic group is as diversified as the rocks which compose it. The charms of Connemara and North-west Donegal, like those of the Central Highlands of Scotland, require no commendation: they are illustrated in the four figures here given from the Geological Survey records.[*] Here are wide stretches of undulating land, generally peat-covered near the sea-board, where excessive moisture from the ocean encourages the growth of lowly vegetation. There, again, are rugged areas, where irregular ridges and knolls of rock protrude above the general level; while the back-ground is usually filled out with massive, often jagged-crested, steeply sloping mountains.

To the areas occupied by quartzite, with its ordinary composition and even by detritus derived therefrom, as amongst the valleys and on the flanks of the Errigal, Nephin, and Maamturk ranges, may be applied the sentence in which Risler stigmatizes an area occupied by similar rock debris in Brittany—"Waste thou wast, waste thou art, waste thou wilt remain."

A chemically pure white sand has long been known to lie on the slopes of Muckish Mountain. It is derived from a peculiar massive quartzite, described by Mr. R. H. Scott[†] as containing "small grains of felspar disseminated through it, as in a porphyry," which facilitates the weathering and disintegration of the rock. Unfortunately, it is so inconveniently situated, that the difficulties of obtaining it are almost prohibitive of its economic utilization.


ABW. from Sk. by A.M'H

Glenbeagh looking S. W. along the line of the great Gwebarra fracture.

---

[*] From Explanation of Sheets 3, 4, 5, &c.

[†] Paper on the Granitic Rocks of Donegal, Jour. Geol. Soc., Dublin, Vol. x.

CHAPTER VI.

Cambrian and Silurian.

The strata belonging to these Formations are the oldest known definitely recognizable by means of their fossils. They consist chiefly of greenish gray, and blue grit, with green, gray, and purple slate, irregularly alternating in stratigraphical arrangement—the grits in certain places having been converted into quartzites, and the slate into mica-schist. They occupy a large area of the country, in all about 4,736 square miles, extending along the eastern coast, from Dublin southward almost to Dungarvan Bay, and from Balbriggan northward by Dundalk to Belfast Lough, except at a few points where newer strata intervene. From the coast they spread inland to Baltinglass in Wicklow, except when interrupted by the great outcrop of the Leinster granite; and almost to the Shannon westward from Down and Louth, forming a triangular area, which comprises the counties named, as well as parts of Monaghan, Cavan, Longford, Leitrim, and Meath. Within that area, however, occur some small tracts of more recent sedimentary rocks, and of igneous rocks—granite, gabbro, &c.—in the regions of Mourne and Carlingford.

Isolated Silurian Areas.

A tract of Silurian rocks lies around Pomeroy in Tyrone; and, in the centre of Ireland, several isolated areas of Silurian grits and slates occur, cropping out from beneath the newer strata which surround them; they form groups of low hills which overlook a wide extent of the adjoining country, the latter being flat and low-lying. In these hills, therefore, is exhibited the phenomenon of rocks, stratigraphically lower and older, forming the higher ground.

Such tracts—*inliers*—denuded of their former covering, are to be seen at Rooskey, Longford, and Chair of Kildare, as well as in Slieve Bloom hills in Queen's County; Slieve Aughty, Slieve Bernagh, and Cratloe hills in Clare; Slieve Arra, Keeper Hills, Galtees and Slievenaman in Tipperary, Limerick, and Kilkenny, and a large area lying to the west of Waterford. An area of Silurian rocks also occurs to the south of Clew Bay; and islands off the coast of South Mayo and North Galway consist of similar rocks. Between Charlestown and Ballaghaderreen, in South Mayo, occurs an interesting tract; and two other small areas of Silurian strata are known to exist in the Dingle promontory.

Of all the areas mentioned, that lying to the south of Clew Bay is the most interesting from a lithological point of view. Nowhere else, perhaps, is so great a variety of strata presented within so small an area, and limited to one Formation. All the members of the Silurian system, except perhaps Arenig, are to be met with, viz., Llandeilo black shale, Bala limestone, Caradoc sandstone and conglomerates, Lower and Upper Llandovery, Wenlock and Ludlow. Conglomerates are to be seen near Lough Mask containing pebbles up to two feet in diameter; and every gradation of such rock and of grit, is to be found, down to the finest arenaceous variety. Shale, slate, and mica schist, with intermediate varieties—phyllites and sericite schist—occur in the region; in some of these argillaceous beds, the most delicate fossil forms are preserved, while in others, all such relics of ancient life are obliterated by metamorphism. The grits, too, have suffered such alteration in certain places, that amongst the newest members, gray grit (of the Wenlock stage)* has been converted into quartzite, as in Croagh Patrick.

Important beds of limestone of Bala age, associated with igneous rocks, occur near Lough Mask and Lough Nafooey; and interesting bands of earthy limestone, and calcareous slate and grit, form a large part of the Wenlock member of the Silurian Formation south of Clew Bay. The same character of limestone is to be found in the area of Silurian rocks between Charlestown and Ballaghaderreen.

Scenery of the District.

From the rocks described above, the agencies of denudation have sculptured an array of scenic features which are sublimely imposing and picturesque. Rising from the shores of Clew Bay is the Croagh Patrick range, culminating in the celebrated conical peak, 2,510 feet above the sea. In the same region occur the precipitous ranges of Sheeffry, Bengorm, Formnamore, Leenane, and Maam, with their massive flat-topped and terraced hills, the chief of which is Mweelrea, 2,688 feet high, overlooking the entrance to Killary Harbour. The harbour is a strikingly picturesque arm of the sea running some nine miles inland, and is the principal one of several deep valleys which sever the mountain groups; others of these sublime valleys are the gorges of Delphi, Doo Lough, and Lough Nafooey.

Throughout the other Cambrian and Silurian areas of Ireland, alternations of fine grit and slate prevail, further varied by the intercalation of conglomerate bands and rarely those of limestone. The limestone bands are of Bala age, and occur in parts of Dublin, Kildare, Wexford, and Waterford. Slate predominates in certain places, grits in others: in Dublin, Wicklow, Wexford, and Mayo the grits have in certain places been converted into quartzite.

---

* The quartzite and accompanying rocks of Croagh Patrick were formerly believed to be metamorphosed Lower Silurian strata. See report of Director-General for 1896 and 1897.

Calcareous Strata.

If a line be drawn from Copeland Island off the Down Coast, by Lisburn, Gilford, and Cavan, to Lough Gowna in Longford, the Silurian strata occurring to the south-east of that line, and generally throughout the central and southern tracts, and those of Dublin, Wicklow, and Wexford, are prevailingly calcareous, while the strata to the north of the line are not so characterized. This is an important consideration to agriculturists.

Very frequently, too, the grits, especially of the strata south of the line above-mentioned, contain a considerable proportion of felspar, which yields potash, and it is probable that the clay-slate accompanying the grits is not deficient in this useful component.

Soil Characters.

It has been stated above, that the Silurian grits throughout Ireland, except to a considerable extent in Connaught, and a very minor extent elsewhere, are usually fine-grained, and alternate with those of slate. The soils resulting from their disintegration therefore are usually fine, mellow, and easily cultivated, especially when the grits predominate. They consequently form a good plant bed, admitting of satisfactory root-development; and, with a small quantity of calcareous matter supplied by the rocks, the soils, even when shallow, contrast very favourably with the coarse, gravelly, heather-covered peaty soils, which thinly cover, or lie in the hollows of, the usually rugged surface of the margining Old Red Sandstone ground—in Clare, Tipperary, Kilkenny, and Waterford.

Risler* states that full manuring, with lime, potash, phosphoric acid, and nitrogenous substances, was necessary for the production of a crop from the Silurian soils at Grandjouan, as represented by M. Rieffel, Director of the Agricultural School of that place—both in the cases of wheat and buckwheat. With phosphate of lime only, there was less than two-thirds of a crop of wheat, and about three-fourths of a crop of buckwheat; the results with sulphate of ammonia, and without (farmyard) manure, were not worth recording. These results indicate a decided deficiency in potash, and illustrate the necessity for supplies of the mineral components lime, potash, and phosphoric acid, if nitrogenous manures are to have their due effect. The case is probably very similar with soils derived from Irish Silurian rocks, for even where lime and potash occur in the *rocks*, there is a great likelihood of deficiency of these substances and of phosphates, in the *soils*, in our very wet climate.

* *Géologie Agricole.* Vol. I., pp. 143, 144.

M. Risler also gives* analyses by Dr. Voelcker, of Llandeilo black schist at North Wales, which shows this rock to be, at some points, extraordinarily rich in phosphoric acid. This character, unfortunately, is exceptional, and it is not possible readily to distinguish the portions rich in this substance, from those which contain small quantities. Black slate appears also in the Silurian strata of Ireland—in Mayo, Galway, Clare, Waterford, Wexford, Dublin, Meath, and Down; but, so far as has been ascertained, no vein very rich in phosphate occurs in these places. The figures of Dr. Voelcker's analyses are as follows:—

—	No. 1.	No. 2.	No. 3.	No. 4.
Organic Matter and Loss,	6·16	4·87	6·25	3·67
Phosphoric Acid, ...	25·35	24·78	23·31	26·88
Lime, ...	33·58	35·98	28·19	35·36
Magnesia, ...	0·31	0·13	5·22	0·26
Iron Oxide, ...	0·01	1·08	0·58	1·89
Alumina and "Fluor," ...	1·06		1·21	5·38
Carbonic Acid, ...	—	—	12·01	—
Sulphide of Iron, ...	7·52	7·84	2·79	3·62
Sulphuric Acid, ...	0·17	0·21	0·16	—
Insoluble Matter, ...	24·84	25·11	20·28	22·94
Total, ...	99·00	100·00	100·00	100·00

Silurian Slate-rock.

A wide band of slate-rock runs eastward, from Broadford in Clare, across the southern part of Lough Derg, into the Arra hills in Tipperary. This band has been quarried at several points for roofing purposes, though only at one place, Portroe, east of Lough Derg, is the slate worked successfully. It is known as the Killaloe slate, though the quarries are some seven miles north of this town. Slate-rock exists at several other points in the inland Silurian tract north of Mitchelstown—in Tipperary; at the Victoria and Ormonde slate-quarries in Kilkenny, north of Carrick-on-Suir; at Carroll's Cross and Glenpatrick in Waterford; south of Westport in Mayo, and many other places.

Two analyses of Irish slates have been given on p. 21; these, with two others on the next page from Dr. Fream's book† will sufficiently indicate the nature and quantities of the substances which slates usually contain; Irish slates frequently effervesce with acids, showing that they contain carbonate of lime. A partial analysis, by the writer, of a sample of Killaloe slate taken at haphazard, the results of which are also stated, will serve for comparison.

---

* *Op. cit.*, Vol. I., p. 178.
† *Op. cit.*, p. 18.

ANALYSES of SLATE.

Chemical Constituents.	Roofing-slate (Wales). (Haughton).	Roofing-slate (Camelford). (Phillips).	Killaloe Slate.
Silica, . .	60·50	58·35	57·52
Alumina, . .	19·70	22·04	
Lime, . .	1·12	0·39	2·87
Magnesia, . .	2·20	1·10	3·03[*]
Potash, . .	3·18	2·45	
Soda, . .	2·20	1·23	
Iron Protoxide, .	7·83	2·57	
„ Peroxide, .	—	6·96	
Titanic Acid, .	—	0·23	
Carbonic „ .	—	—	4·40
Water, . .	3·30	4·60	
Totals, .	100·03	99·92	100 .

[*] As carbonate.

Physical Features.

With the exception of the rocks of the western area—the physical features of which were described on page 65—those of the Cambrian and Silurian Formations do not form hills of great height. In the north-eastern region, they occupy for the most part an undulating tract of low average elevation, the chief eminences being Loughanleagh (1,116), near Bailieboro', and Slieve Glah (1,057), south-east of Cavan. In Wicklow and Wexford, several hills of moderate elevation dot the Silurian area, mostly formed of arenaceous strata transformed into quartzite. The principal hills are Croaghan-Kinshela, 1,987 feet above the sea, on the confines of Wicklow and Wexford; Sugar-loaf mountain (1,659), Kirikee mountain (1,559), and Trooperstown Hill (1,408), in Wicklow; and Slieve Boy in Wexford. The diversity and arrangement of the rocks of this district, and the difference of degree and manner in which they yield to denudation, have resulted in a character of scenery which presents an attractive combination of beauty and grandeur; hills of massive proportions and varied outline, striking conical peaks, solitary and weird cooms with their mountain-embosomed tarns, deeply cleft glens and wooded vales; rivulets, cascades, rushing streams, and meandering rivers—all combine to render the region of Wicklow and its borders justly celebrated.

The Silurian districts in Central Ireland for the most part present irregular groups of gently swelling hills, rendered striking in some instances by more or less horizontally imposed and truncated cappings of Old Red Sandstone. The Keeper Hill to the south of Nenagh, and Devil's Bit east of that town, may be mentioned as examples. The latter is represented in the accompanying woodcuts. (Figures 17 and 18). *

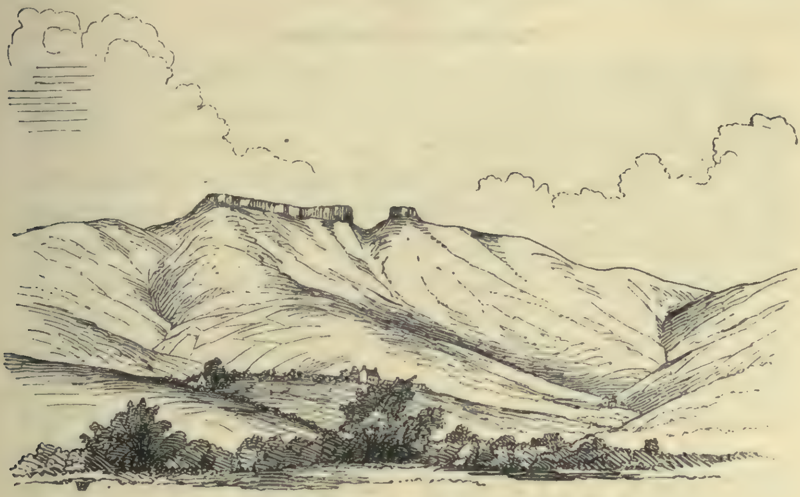


Fig. 17. The Devil's Bit from the north.

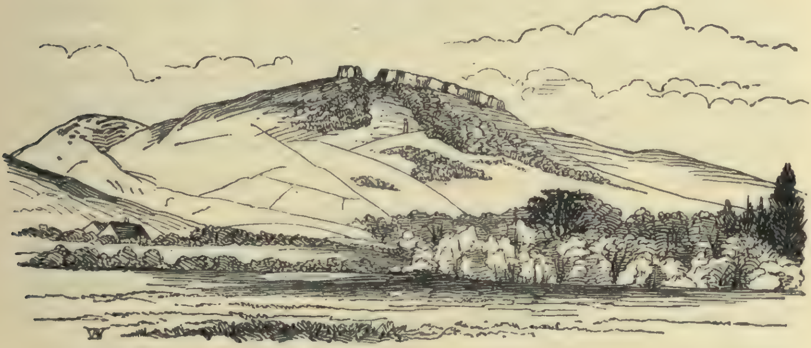


Fig. 18. The Devil's Bit from the southward, distance about 5 miles.

While the Silurian rocks weather more slowly than the neighbouring limestone strata, the intervening Old Red Sandstone, when present in force, yields more slowly than either. The result of this is well seen in the Galtee, Slieve-na-man, and Comeragh regions, where the Old Red Sandstone towers above the Silurian tracts; the latter thus form hill-enclosed plateaux some 400 feet higher than the Carboniferous area.

The hill-tops and flanks of the Silurian ground are thinly covered with a coating of directly derived soils. In the lower parts and the valleys, however, thick accumulations of detritus are usually to be found. This detritus is probably Drift, though the distance of its transplacement may be insignificant. That the accumulations in certain

---

* Taken from Explanation of Sheet 135, p. 6.

places present evidence of having been transported from distant localities will be shown in a future chapter.

Facilities for Irrigation.

The undulating character of much of the Silurian ground, with regular and, to a great extent, unbroken curving profiles—as indeed shown in the two previous sketches—suggests its suitability for improvement by irrigation. Even when a deficiency of lime is noticeable in the soils derived from the Silurian strata, the spring water flowing from these strata, and trickling through the rubble which frequently forms the subsoil, is impregnated with a proportion of carbonate of lime, and is often quite "hard." It is unfortunate that circumstances, apparently trifling, but calculated in the aggregate to be of great advantage to agriculturists, and for this reason scrupulously recorded at numerous foreign agricultural stations, have hitherto been overlooked in this country. The contents of the waters flowing over the different rock Formations might be reckoned amongst such circumstances; but systematic analyses of water, any more than of a typical series of the country's soils, do not seem to have been attempted. Such analyses of waters in the case of the Silurian Formation would probably reveal a good proportion of lime, and a not inconsiderable percentage of potash, as well as some phosphoric acid. These are carried away in the drainage, and irretrievably lost to husbandry. Were they conserved, and applied to the land by suitable irrigating systems, how profitably they would supplement the resources existing in the soil.*

M. Risler, Director of the Agricultural College at Paris, will scarcely be regarded as an Utopian theorist; and he sets so high an estimate upon such means of enhancing the productiveness of land, that he writes† :—"The distribution of waters, as that of mineral matters, depends upon the geological constitution of a country. By regulating their flow according to the needs of nourishnent of agricultural produce, the wealth of France could be doubled." Necessary demands upon a soil's resources are sufficiently great, and the expense of artificial fertilizers forms so considerable an item upon the debtor side of the farmer's accounts, that the prevention of continuous waste, when at all consistent with economy, is an object which well merits his attention.

---

* For further remarks upon irrigation, the degrees of hardness of lime waters, and the advantage in husbandry, the reader is referred to p. 78.

† *Op. cit.*, Vol. I., p. 14.

CHAPTER VII.

OLD RED SANDSTONE.

This Formation stretches over the greater part—more than half—of the County of Cork, where it forms the Magillicuddy Reeks and the mountainous tracts of the Iveragh promontory. It also forms the hilly ground lying between Kenmare River and Bantry Bay, and the minor promontories, which in Cork extend southwestward into the Atlantic. Rocks which are supposed to correspond in age, known as the Dingle Beds, form the promontory north of Dingle Bay. From Cork, the Formation extends into Waterford and Tipperary, where it forms the Knockmealdown and Comeragh mountains, and thence into Kilkenny. It forms the cores of hills in Limerick, or fringes the Silurian cores described in last chapter, in that county, Tipperary, Clare, King's and Queen's counties, and elsewhere in central Ireland. Still further north, strata of this Formation are to be seen throughout the large area around Fintona in Tyrone, which stretches northeastward from Enniskillen to Pomeroy.

It may be judged, from the manner in which the strata pass beneath those of the Carboniferous Formation and repose in isolated patches (outliers), here and there upon Silurian rocks, that the Old Red Sandstone had once a very wide extension throughout Ireland. The conclusion is strengthened by the occurrence of other outlying patches which have escaped denudation, at Draperstown in Londonderry, as far north even as Cushendun in Antrim, and Fanad in Donegal, as well as at Donabate near Dublin, and near Westport in Mayo.

Lower and Upper Divisions.

The Formation is usually described in two divisions, namely, Lower and Upper Old Red Sandstone. The reason for the distinction is not obvious in the County of Cork; for throughout that county the rocks form a continuous series which passes up by regular sequence into the strata of the Carboniferous system. In the North of Ireland, however, Carboniferous strata, including some at the base of the system, which resemble Upper Old Red Sandstone of Scotland, are separated by a great stratigraphical break—an unconformability—from the Lower Old Red Sandstone of the Fintona tract. In Kerry a similar discordance of a very striking character occurs, to which reference will be made. In the Iveragh promontory, West Cork, an immense Old Red series, known as the Glengarriff Grits, is to be seen, consisting of red, green, and purple highly micaceous grits, with occasional conglomerate beds and green and purple slate. A characteristic feature of the series is that it contains thin bands of compact limestone, and of highly calcareous grit, all of which are commonly known as "cornstones." It is overlain in regular succession by Upper Old Red Sandstone, and, taken together, the series attains a thickness of 13,000 feet. The Glengarriff grits pass laterally into the Old Red Sandstone of East Cork and Waterford, which consists of red sandstone, often argillaceous, with "cornstones." This likewise passes up into Upper Old Red Sandstone without a break or any striking lithological change. The thickness of the Formation here drops to 9,000 feet in East Cork and even to 5,000 in Waterford. The lowest beds of the Formation in Kilkenny and at Galtymore, consist of massive red conglomerates resting upon the upturned and denuded edges of Silurian strata, as shown in the woodcuts on page 49. The same arrangement of strata is noticeable in South Galway (Fig. 19*), where Upper Old Red conglomerates sandstone and shale crop out, rising from beneath the limestone of the plain, and partially concealing the Silurian strata of the Slieve Aughty hills, on the west side of Lough Derg. The unconformability thus illustrated may be observed in several stream courses on the slopes of the neighbouring groups of Sl. Bernagh and Sl. Arra, as well as on Slieve Bloom in Queen's Co., Slievenaman in Tipperary and Slieve Baun in Roscommon. The thickness of the Upper Old Red series in these areas is inconsiderable for the width of outcrop presented, since the beds dip with the slope of the ground. The same may be said of the Old Red Sandstone which skirts the metamorphic ground north of Clew Bay. The Old Red beds to the north-east of the bay, and at Old Head and Clare Island, at the entrance to the bay, are probably Lower Old Red, as are those of the Curlew Hills, near Boyle and the Fintona tract: while those which form Slieve Dart and Mount Mary, in North Galway are Upper Old Red.

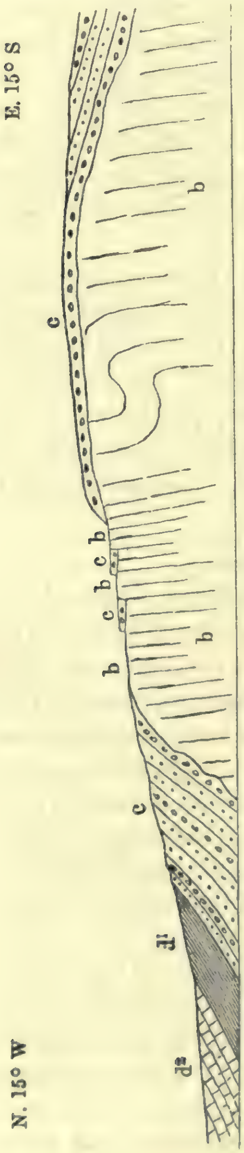


Fig. 19. Section through the hill S.E. of Roxborough, South Galway. Bearing W. 15° N.

d² Lower Limestone.
d¹ Lower Limestone shale.
c Old Red Sandstone.
b Silurians.

Scale—Horizontal and vertical, 6 inches to one mile.

---

[*] From Explanation of Sheet 115 and 116, p. 20.

Oldest Land Plants.

The conglomerates above-mentioned pass upward into liver-coloured sandstone and shale. At a celebrated fossil locality, at Kiltorcan in Kilkenny, the Old Red Sandstone contains yellowish-green compact grit beds, which have yielded some remarkably beautiful fossil ferns, *Palæopteris* (*Andiantites*) *Hibernica*, and an estuarine mussel shell, *Anodonta Jukesii,* which may be seen in the Geological Survey Collection in the National Museum.

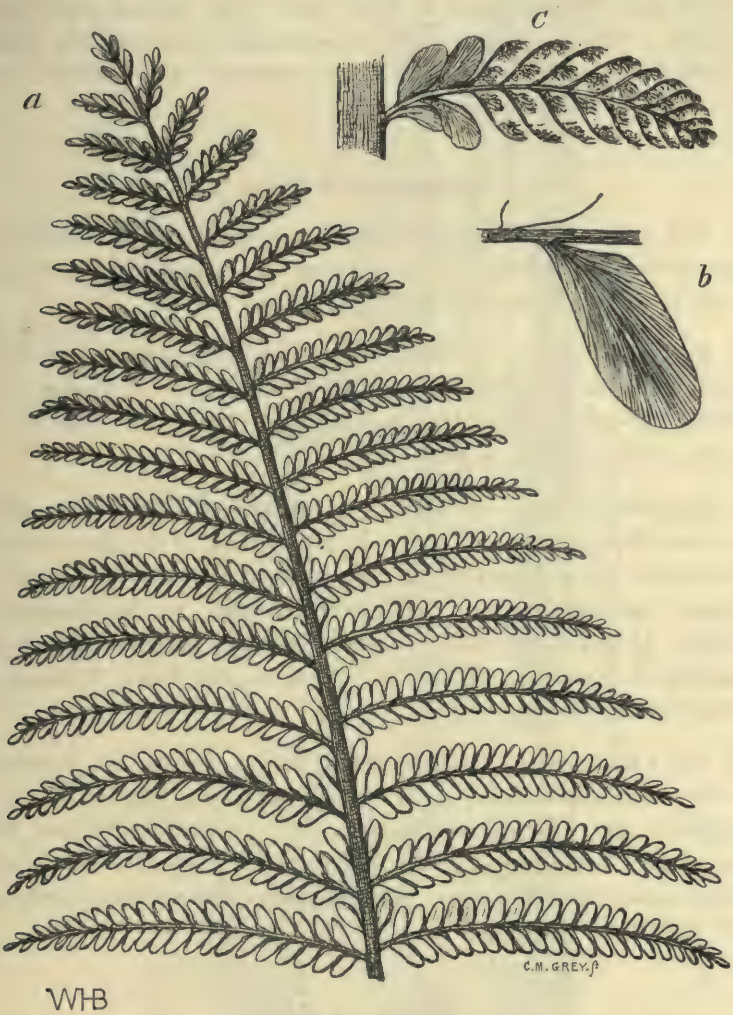


Fig. 20. Old Red Sandstone tree-fern, first described as *Cyclopteris Hibernica* by E. Forbes; also known as *Adiantites Hibernicus,* Adolphe Brongniart; and *Palæopteris Hibernica,* W. P. Schimper. *a.* Portion of frond, one-sixth natural size; *b.* one of the leaflets, natural size, *c.* a single branch in fructification taken from another specimen.

---

* Taken from Explanation of 147 and 157, p. 14.

The fern is especially interesting as forming the chief member of the earliest group of land plants, of which remains have been met with in Ireland; as well as being the precursor of an important class which attained remarkable development during the Coal Period. *Palæopteris* has also been found near Ballyhale, at Jerpoint near Thomastown, at Tivoli near Cork, and at some other points. The proportions of the handsome frond may be judged from the figure here given, which is one-sixth of the natural size.

Munster and Ulster.

The Lower Old Red Sandstone lessens considerably in thickness in the regions last mentioned, and does not appear in the Tipperary hills, Clare, nor in the central Irish counties.

Both divisions of the Formation appear in the promontory which terminates in Kerry Head, and to the south-west of Tralee. The Lower Old Red beds there rest unconformably upon the Dingle beds. (See Woodcut on page 48.)

This discordance is a perplexing geological fact upon which it would be out of place here to dwell. It must suffice to say that eminent geologists have classed the Dingle beds as Lower Old Red Sandstone, because of their striking resemblance to the Glengarriff grits. If this judgment be correct it involves the unusual circumstance of a great stratigraphical break *in* the Lower Division of the Old Red Sandstone.

The Fintona series consists of red, purple, and brown sandstone, with conglomerates in many places, made up chiefly of felsite pebbles, and felspathic particles.[*] No "cornstones" have been met with in the Tyrone Old Red Sandstone; their absence is an important point of contrast between these rocks and their congeners in the South of Ireland.

Physical Features.

The Tyrone tract presents no very notable natural features; the chief hills are Slievemore (1,033 feet above the sea), near Ballygawley; and Brocker Mountain (1,046), and Topped Mountain (909), near Enniskillen. Two escarpments run north-eastward, one along the southern boundary of the tract by Killyfaddy towards

---

[*] A full description of the formation, with lucid notes, comparing the rocks in various regions, is to be found in a Paper by the late J. Nolan, M.R.I.A.

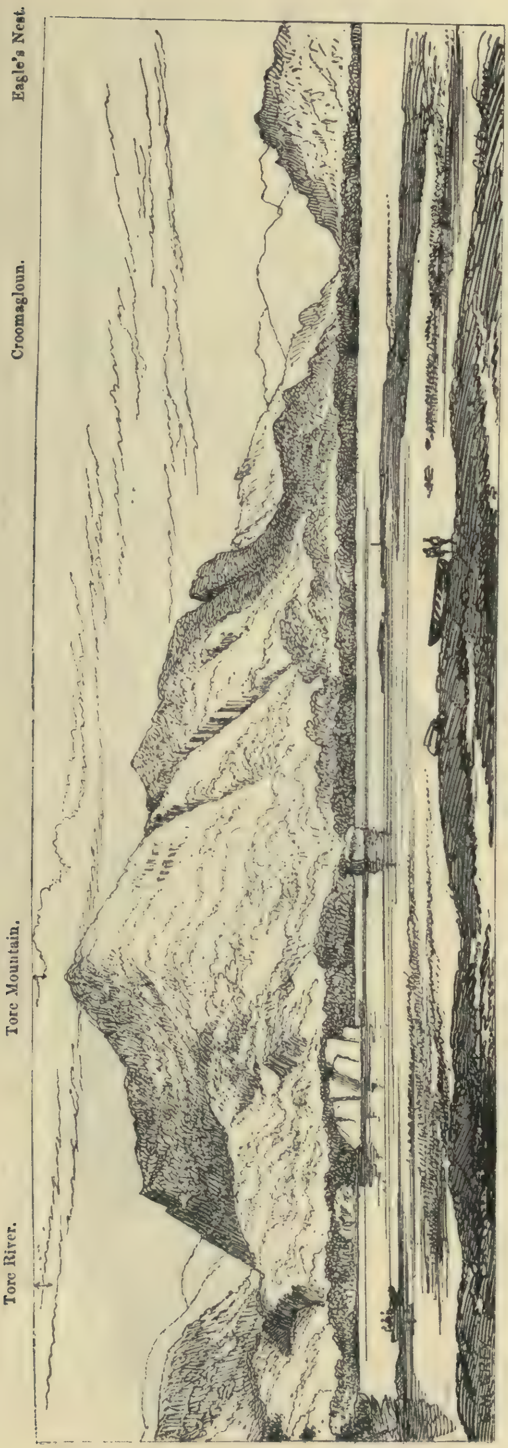

Torc River.
Torc Mountain.
Croomagloun.
Eagle's Nest.

Fig. 21. View of the Mangerton Range from the Lake Hotel. Lower Lake, Killarney.

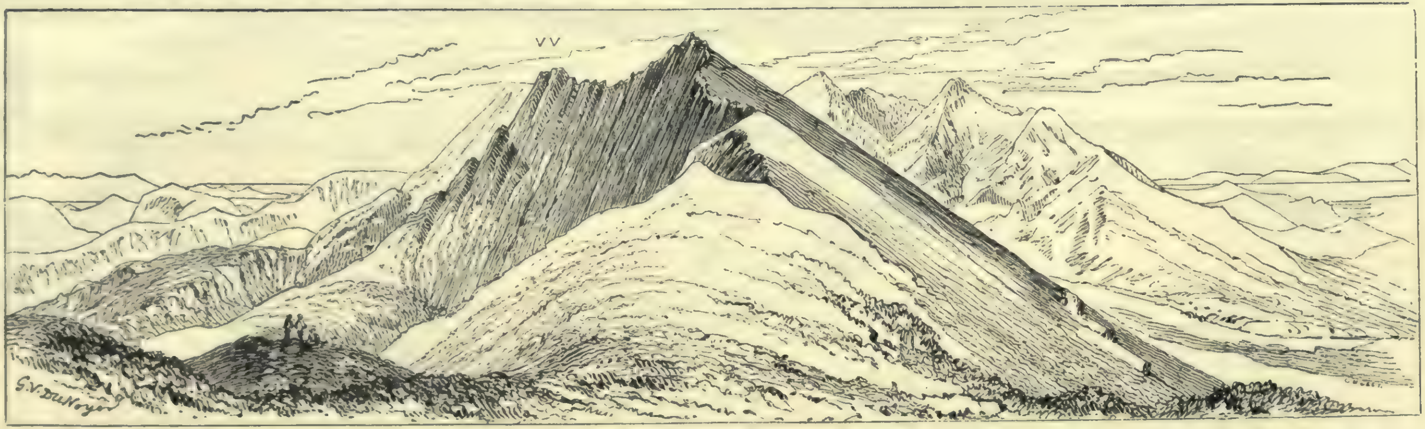


Fig. 22. View of the Reeks looking west from the summit of the ridge west of the Gap of Dunloe; Carrantuohill Mountain in the distance, with Dingle Bay to the extreme right. On the left of the view is the head of the Black Valley, with the entrance to Kenmare Bay beyond.

Ballygawley, and another by Fintona and Seskinore. These escarpments, and several of the valleys and glens which traverse the area, are considerably picturesque.

The Old Red Sandstone in the south forms some of the highest mountains in Ireland, with striking escarpments, cooms, and picturesque hill cappings. Those upon the Keeper and Devil's Bit hills have been already mentioned. The massive cappings upon the Silurian rocks in Galtee Mountains overlook the area of the latter rocks, which form the western portion of the range, and rise to the height of 3,015 feet in Galtymore. The sublime background to the celebrated scenery of the Killarney Lakes—the Magillicuddy Reeks, with their valleys and glens—is carved out of this Formation. The massive features of Carrantuohill (3,414), and Mangerton (2,756), of the Reeks, form the nucleus of a group which extends into the Iveragh and Glengarriff promontories. The character of the scenery is well depicted in the foregoing views (Figures 21 and 22).*

The Dingle promontory also, culminating in Brandon Hill (3,127) and Benoskee (2,713), consists, as has been stated, almost entirely of rocks supposed to be of Old Red Sandstone age.

Soils of the Formation.

The strata, consisting of slate or shale with red and green sandstone—sandstone predominating—in general give free-working soils, with the probability of a goodly supply of potash in those places where highly felspathic grits and conglomerates are met with, as in the Tyrone Old Red area. Comparing this area with the Old Red regions of Cork and Waterford, an observer will perceive some difference in the fertility of the soils, in favour of the latter region. This is probably to be accounted for by the Old Red strata in Cork, &c., being on the whole more calcareous than those in Tyrone—a judgment suggested by the occurrence of "cornstones" amongst the Old Red rocks in the southern half of the country, and their absence from the corresponding rocks in the north. The southern strata were laid down in lime-charged waters, in waters at all events supercharged with lime from time to time; † while no evidence for such conditions obtains in the northern area.

---

* From Explanation of Sheets 173 and 184.

† No fossils have been met with in these "cornstones." They have probably been deposited by chemical precipitation from waters highly charged with carbonate of lime; which is present in many of the grit beds, though such may not be sufficiently calcareous to be considered "cornstones."

Irrigation.

The waters flowing from the Old Red Sandstone in Tyrone would doubtless be poor in lime for the purpose of irrigation. They, however, probably contain such a proportion of potash as would justify some expense in distributing them over meadow-land, or pasturage while not being grazed. The amount present in water flowing off granite may, in the absence of more definite information, generally indicate the proportion available in the strongly felspathic grits of Tyrone; and its application to plants on the favourable rooting soil, there afforded by the Old Red Sandstone, should be attended with better results than attend irrigation in the granite regions mentioned by Risler,* and referred to in Chap. X., p. 118 of this book. The waters flowing from rocks in this (Old Red Sandstone) Formation in the south, would probably be found somewhat strongly calcareous, and, consequently, useful for irrigation. In many places throughout the southern counties, Old Red Sandstone, and Silurian rocks, are covered with accumulations of gravel and clay containing limestone boulders and pebbles. The waters flowing therefrom are almost always calcareous, so much so that in some places they deposit carbonate of lime ("marl"), upon the stream banks where they exude, after making their way through soils and subsoils on sloping ground.

Salts in Solution.

The property of waters, known as "hardness," is attributable to their containing salts of lime and magnesia, and occasionally of some other bases, which, with those of potash and soda, are of frequent occurrence, especially in waters issuing from springs. It causes the curdling of soap in the process of washing, by which the formation of lather is prevented, or rather delayed; and upon this delay Dr. Clark based a method of estimating the degree of water-hardness, the principle of which is the ascertainment of the quantity of soap solution, of certain known standard strength, requisite to form lather with a certain quantity of the water to be examined.

Water containing only carbonates loses the power of retaining them in solution, through the escape of an extra quantity of carbonic acid, either when the water is boiled, or when long exposed to the air. For this reason the hardness due to carbonate in solution is spoken of as *temporary*. Frequently, however, water contains sulphates as well as carbonates, and in this case the hardness is known as *permanent*, because boiling does not remove it. For further remarks upon this subject the reader is referred to the chapter on water supply.

---

* See remarks upon the advantages of irrigation, p. 70.

Valencia Island, from the Ferry Point, opposite Knightstown, Co. Kerry.*
From Explanation of Sheets 182, 183, 190, page 20.

CHAPTER VIII.

THE CARBONIFEROUS SYSTEM.

The strata to be described in this chapter cover about two-thirds of the entire surface of Ireland. The Carboniferous System or Formation, therefore, takes the leading place in determining the agricultural capabilities of the country. Part of the ground occupied by it lies above the range of profitable cultivation, or is notably sterile; yet well-nigh half of Ireland is occupied by Carboniferous limestone, which produces earths remarkable for their fertility, and has yielded to soils materials which, as we have seen, stretch far beyond the limits of the limestone tract. So wide a distribution of soils consisting of, or enhanced in value by, limestone detritus, gives character to the entire country, and contributes, conjointly with the humidity of its climate, to win for it the epithet of the Emerald Isle. These rich derivatives are seldom found at elevations higher than 1,000 feet above the sea; for the most part they lie below 700 feet—a condition of no small advantage to the practical agriculturist; for the more elevated a tract, the more likely it is to be cut up with numerous water courses and minor valleys, which render farming operations laborious and expensive. To a large extent Carboniferous strata occupy the low ground, and it will be shown that their *character* is chiefly accountable for their *situation*. It, therefore, becomes obvious that the husbandry is affected in various ways, and for the most part favourably, by the Formation here described.

Scarcity of Coal in Ireland.

The limestone series, when followed to its base, is found to overlie sandstones and shales belonging to the same system, while on the other hand it passes beneath similar rocks, which contain more or less valuable seams of coal in a few places. The scarcity of coal-seams in this country, as compared with England, is attributable to denudation. The uppermost series, which contains the rich seams, once existed here in force, as in England—above the limestone; but it has been almost entirely removed; so that the agencies of denudation which laid bare the great extent of limestone strata of central Ireland, to our advantage in an agricultural way, deprived us of the still more profitable deposits of coal.

The case, therefore, is as follows, viz., the Carboniferous System—its uppermost portion at least—once, in all probability, extended over the entire area now called Ireland,* and, since that epoch, vast quantities of material have been swept off and carried to the ocean. What now exists here is but a small remnant of the former mass; the once underlying strata appear over large regions, or are concealed by a small thickness of Carboniferous rock, along the borders of the Formation; and outliers, or remnants of the original mass, appear in many places.

In presenting a description of the Formation for agricultural purposes, it will be most convenient to do so under the three-fold division above alluded to, and given in the table of Formations at the opening of Chapter IV., commencing here with the lowermost division.

Lower Carboniferous Sandstone and Shale.—This series does not occur extensively, and in several places the Middle, or Lower Limestone series, rests almost directly upon the older Formations. Its basal beds usually contain, or consist of, conglomerate, except when it follows the Upper Old Red Sandstone: here the stratigraphical sequence is unbroken. In the section represented on p. 45 the Formation commences with conglomerate resting upon the contorted and denuded mica-schist of the Ox Mountains. In these here shown (Figs. 23 and 24)† a regular succession is noticeable from Old Red Sandstone upward into Carboniferous rocks; the former resting upon denuded Silurian strata.

It is possible that conglomerates may occur at any point in a Formation or series, as is the case in the Carboniferous strata north of Rush, Co. Dublin. Such an occurrence is, however, unusual, and is to be accounted for by some local disturbance during the deposition of the strata. The usual case is that conglomerates mark the base of the Formation we are dealing with, though as ancient land was subsiding beneath the Carboniferous sea, basal conglomerates may have been forming at newly submerged points, while the Formation itself had reached an advanced stage of deposition in the deeper waters at other points. Thus great thicknesses of conglomerate are to be seen in the vicinity of Dungiven, Ballygawley, Fivemiletown in Tyrone, and along the margin of the metamorphic tract

---

[*] Professor Hull, F.R.S., in his "Physical Geology of Ireland," 2nd ed., p. 187, represents parts of Ireland as never having been covered with strata of this Formation. *Lower* Carboniferous rocks, however, occur at 1,964 feet above the sea on Slieve League, in Donegal, and at 2,200 on Formnamore, in Galway. From these facts it may be surmised that the Upper Carboniferous strata, at all events, which are 3,000 to 4,000 feet in thickness, must have spread over the remaining portions of those counties. Judging also from the published Geological Sections of Wicklow and Carlow, it seems possible that the Carboniferous strata may have overspread the Leinster mountains, even if the lowest beds resting upon the older rock should, in these counties and Dublin, be of Middle Limestone age.

[†] From Explanation of Sheets 117 and 118, p. 9.

Fig. 23.

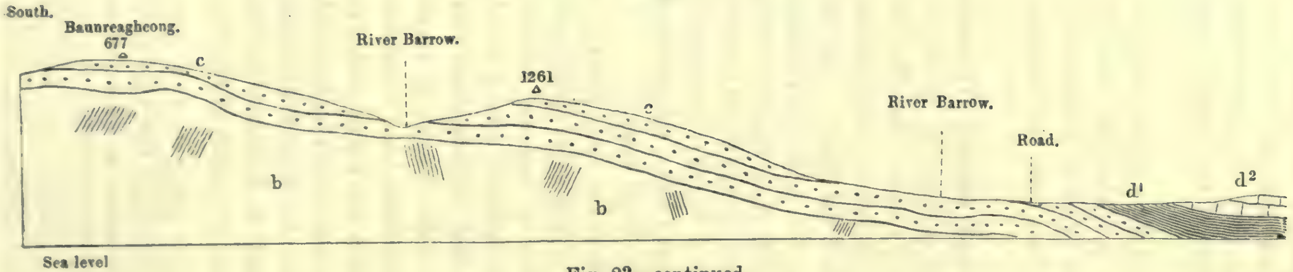


Fig. 23—continued.

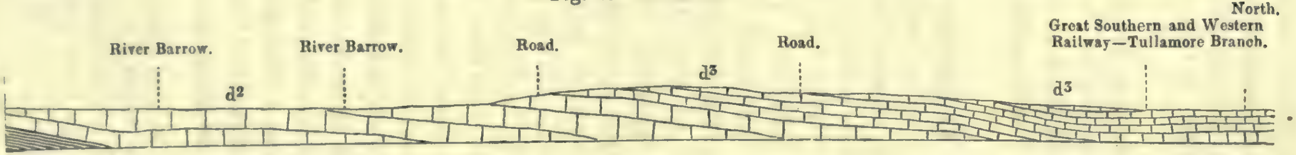
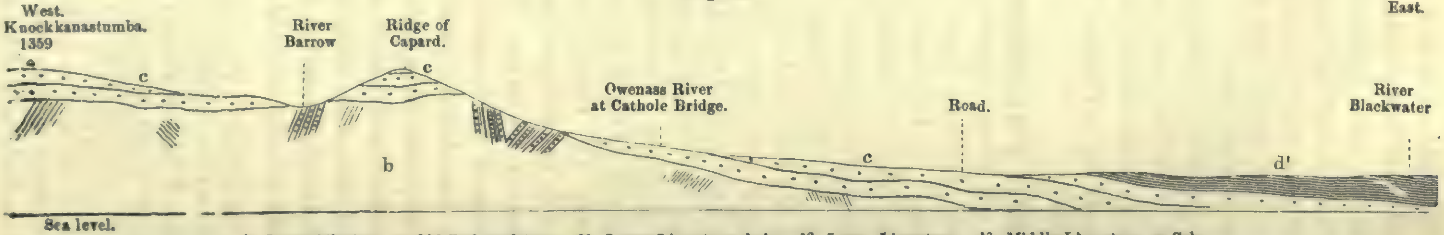


Fig 24.



b. Lower Silurian. c. Old Red sandstone. d^1. Lower Limestone shale. d^2. Lower Limestone. d^3. Middle Limestone, or Calp.
Scale.—Horizontal, 1 inch to a mile; Vertical, 3 nches to a mile.

Figs. 23, 24. Sections across Slieve Bloom, Queen's County in Tyrone and Donegal. Some of these deposits point distinctly to their having been formed against steeply shelving shore-lines of the period; and at Lough Easke, in Donegal, the deposition of such coarse sedimentary rocks was going on, whilst limestone was in process of formation in districts to the south of that place—no more than a few miles distant. Limestone beds traced northward, both at Lough Eask, and in the tract lying to the north of Lower Lough Erne, may be seen to become thinner, and finally to die out, being replaced by arenaceous strata. These circumstances will explain why great thicknesses of sandstone and shale may be found spreading over extensive areas in Londonderry, to the west of Ballina, and elsewhere in the North of Ireland, while the lowermost member consisting of the same kind of strata is insignificant in Central Ireland; and in the South, until we cross an east and west line through the city of Cork. To the south of that line a remarkable change appears somewhat suddenly, reference to which will presently be made.

The Carboniferous rocks above-mentioned chiefly consist of alternating deposits of sandstone and shale, the former usually predominating. The shale may be either dark gray, green or red; and the sandstone, white, yellow, green, gray, red, or mottled, frequently containing white quartz pebbles and pebbly patches or bands. This lowermost member forms no striking natural features, except where remnants of it form flat cappings on hills of older rocks, as in the case of outliers resting upon Slieve League, in Donegal, and upon Formnamore, to the west of Lough Mask, in Mayo.

Soils of this Member.

The soils derived from Lower Carboniferous strata are usually sandy. When shale and slate predominate, the detritus forms a stubborn unresponsive soil. A few unimportant beds of earthy limestone are to be met with amongst the sandstone and shale strata of Dungiven and Draperstown, and amongst those to the west of Crossmolina and Killala in Mayo; but these are not of sufficient consequence to produce an ameliorative effect upon the soils of those regions.

A Table has been given on p. 21, setting forth the constituent parts usual to clays, shales and slates; from which may be judged the soil components yielded by the shales of this member. The following analyses of clays and sandstones also exhibit the nature of the materials which are supplied to soils by Lower Carboniferous strata. The deficiency of the materials in fertilizing substances is very obvious, and sufficiently illustrates the similar disadvantage attaching to soils after Irish strata of the same character. Those of columns 2, 3 and 4 of the table are taken from Professor Green's Physical Geology (p. 177); of the remaining analyses, col. 5 is from "Soils and their Properties," by Dr. Fream (page 39), and col. 6 gives the result of analysis by Messrs. A. Norman and Tate, of sandstone—"Shamrock Flagging"—quarried by Messrs. A. Watson & Co., near Liscannor, Co. Clare :—

Chemical Constituents.	Common Pottery-clay.	Fire-clay (Stourbridge).	Coarse sandy China-clay.	Carboniferous Sandstone (Heddon).	Sandstone flagging (Liscannor).
Silica, ...	49·44	65·10	66·68	95·1	84·90
Alumina, ...	34·26	22·22	26·08	2·3	6·60
Iron Peroxide, ...	7·74	1·92	1·26		–
„ Protoxide, ...					3·60
Lime, ...	1·48	0·14	0·84	0·45	0·90
Magnesia, ...	1·94	0·18	trace,	–	1·26
Alkalis, ...	–	–	–	–	0·30
Acids, &c., ...	–	–	–	0·25	0·65*
Water, ...	5·14	9·86	5·14	1·8	1·70
Totals, ...	100·00	99·42	100·00	100·0	100·00

* Manganese oxide.

Carboniferous Rocks of Cork.

The Carboniferous rocks of South-west Cork do not assume the threefold division mentioned on page 81. They consist of grits and slate, known as "Coomhola Grits" and "Carboniferous Slate," which, conformably overlying the Old Red Sandstone, pass up in regular order of succession into Coal Measures,* *i.e.*, the lowest portion of the upper division of the system. This may be seen near Bantry, Bandon, and Ballinhassig. In all, the grits and slate there attain a thickness of 5,000 feet. There is no doubt that sedimentary rocks were being deposited in this south-west region, while limestone was in process of formation elsewhere over the Irish area, and even so near as at Cork and Kenmare: for at both these points limestone forms a part of the Carboniferous system.

A diagram,† published by the late Professor Jukes, explains the relation of the two classes of components in the series as a whole, the limestone beds dovetailing with the slates and grits, a condition of deposition resembling that already described as occurring in the North.

---

* Jukes compared the black slate of S. Cork to the supposed Coal Measures of Dublin which, since 1864, have been relegated to Yoredale, and Millstone Grit,

† Explanation of Sheets 187, 196, p. 36.

Deformation of Strata.

The Carboniferous rocks, and those which preceded them in Cork and Waterford, have undergone deformation and crumpling through intense compression within the crust, as already illustrated by woodcut on pages 46, 47. Slate has in this manner been formed, so perfectly that it has been worked for roofing purposes near Roscarberry, and to the north of Bantry. The strata, through the same agency, have been thrown into a series of convolutions—synclinal and anticlinal curves—resulting, through the more rapid weathering of the Carboniferous strata, in the formation of a series of east and west ridges of Old Red Sandstone. These are represented in the following sections (Figs. 25* and 26†):—

The Carboniferous slate and grits in Cork yield a cold and stony soil, though these conditions are modified by a mingling of more propitious materials drawn from the Old Red Sandstone ground, and modification is effected in a remarkable instance, by deep limestone drift, at the head and on the south side of Bantry Bay, reference to which will be made later on.

The Middle Series.—This consists chiefly of limestone, and occupies in all about 13,500 square miles of Ireland, including portions concealed by drift, peat, alluvial deposits, and water. In colour, the limestone may be blue, light or dark gray, or occasionally yellowish, and sometimes stained reddish with iron oxide. It may be compact or partially crystalline in texture; frequently contains numerous fossils; and in many places beds of limestone contain chert, sometimes to the extent of forming more than half the mass. This silicious substance contains fossil micro-organic forms, and occurs either as irregular nodules, or as layers in or between limestone beds. The fantastic shapes often assumed by both nodules and layers are illustrated in the sketch on page 87 representing a few beds of cherty limestone (Fig. 27‡).

Carboniferous Limestone.

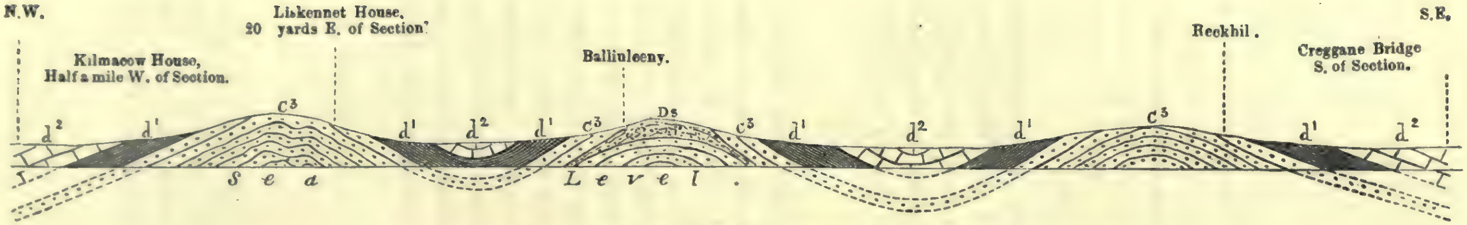
The limestone may form massive beds or occur in layers less than a foot in thickness. It is frequently flaggy, and the flags or thin beds are often separated by partings of shale, which testify to the intermittently muddy condition of the sea in which the rock was

---

* From Explanation of Sheet 153, p. 16.

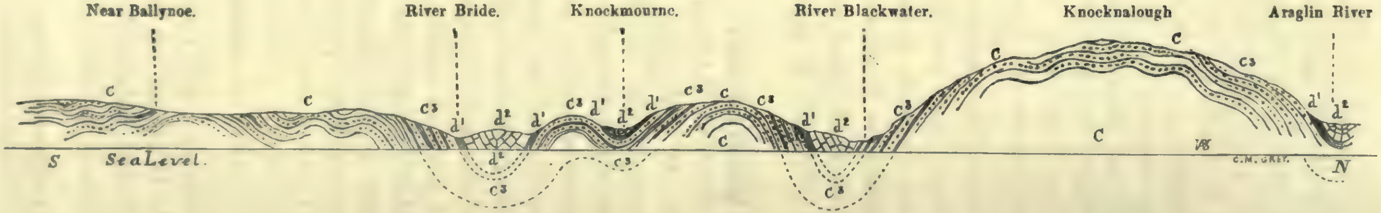
† From Explanation of Sheet 176, p. 12.

‡ Taken from Explanation of Sheets 163 and 175, p. 13.


N.W.
Kilmacow House, Half a mile W. of Section.
Liskennet House, 20 yards E. of Section'
Balliuleeny.
Reckhil.
Creggane Bridge S. of Section.
S.E.
d²
d¹
c³
d¹
d²
d¹
c³
Ds
c³
d¹
d²
d¹
c³
d¹
d²
Sea Level.

Scale:—Horizontal, 1 inch to a mile; Vertical, 3 inches to a mile.
d² Lower Limestone. d¹ Lower Limestone Shale. c³ Upper Old Red Sandstone. Ds. Trappean Ash.

Fig. 25. Section across Old Red Sandstone ridge in County of Limerick.



Scales: Horizontal, 1 inch to 9,000 feet. Vertical. 1 inch to 2,000 feet

Fig. 26. Section across part of Cork, showing crumpled strata in anticlinal, and steep synclinal folds.

formed. The shaly layers may assume the magnitude of beds, alternating with those of limestone; and often muddy conditions prevailed while the limestone was in process of formation, in which case it is found to be earthly—argillaceous or arenaceous, or both. Indeed, mud and sand may usurp the place of carbonate of lime to such an extent as to form a rock which might be styled a calcareous shale or sandstone. All these varieties are to be met with in the Carboniferous limestone series; and in certain places throughout Ireland, the limestone contains considerable quantities of magnesia: so rich is the rock in this substance at some points, that its extraction as a commercial product would be remunerative. A profitable industry of the kind has been carried on by the Messrs. Jennings, of Cork, for many years past. The following high percentages were found by Sir R. Kane in specimens taken in dolomitic areas in Sligo (1), Dublin (2), and Kilkenny (3), viz.:—

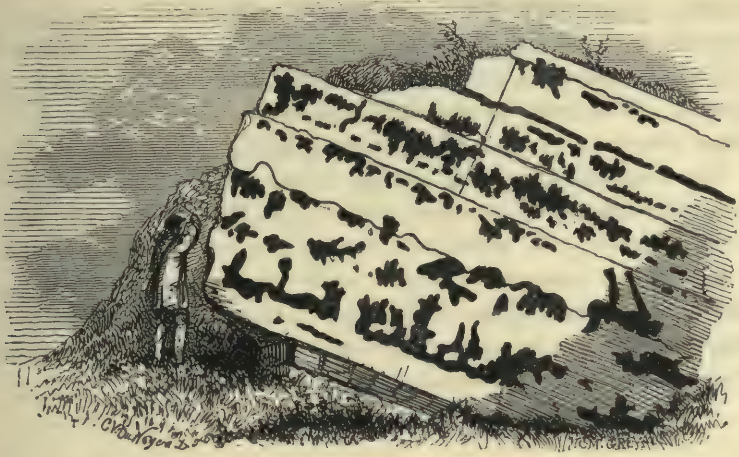


Fig. 27. Chert in Upper Limestone, N. of Newmarket, Co. Cork.

—	I.	II.	III.
Lime, ...	30·3	30·2	30·13
Magnesia, ...	22·1	20·6	21·43
Oxides of Iron and Manganese,	0·6	1·5	·95
Silica, ...	–	1·5	5·74 ?
Carbonic Acid, ...	47·0	46·2	46·65
	100·0	100·0	104·90 ?

"Calp"—Earthy Limestone.

The middle portion of the limestone series is characteristically earthy, occurs in thin and flaggy beds, weathers rapidly, and yields poor lime. It is technically known as "Calp," and has a wide distribution throughout Dublin, Meath, Westmeath, Longford, East Galway, Fermanagh, Tyrone, and Sligo. This earthy limestone is replaced by sandstone to the west of Lower Lough Erne, and south of Donegal Bay, as well as near Lough Eask, north of Donegal (town). Westward, on the north side of the bay, Calp assumes its usual character—very earthy limestone or calcareous shale.

The Calp usually yields a cold, highly-retentive, and stubborn soil, while the purer limestone (which is usually light gray in colour) gives a shallow, rich, warm soil, bearing a highly nutritious herbage—as may be observed in cases where Drift does not cover the rock and its immediate derivatives. Intermediate varieties of limestone afford soils which are not deficient in lime, and, containing much clay, also probably contain a proportion of potash.

Phosphates in Limestone Soils.

The importance of phosphoric acid as a soil constituent has already been dwelt upon, and perhaps cannot be overestimated. Its presence in the form of phosphate in lime-soils and subsoils, may be safely assumed, inasmuch as few kinds of limestone are devoid of this valuable salt. The following analyses of three varieties of limestone by Dr. Hodges, give the quantities which may be commonly reckoned upon in Ireland, viz:—

1. Maghera, Co. Londonderry.
2. Moira, Co. Down.
3. Castle Espie, Co. Down.

——	I.	II.	III.
Carbonate of Lime, ...	98·63	96·80	94·40
" " Magnesia ...	0·38	0·76	1·38
Phosphate of Lime, ...	0·10	0·12	0·05
Oxide of Iron and Alumina, ...	0·08	0·40	0·40
Silica and Clay, ...	0·45	0·56	2·40
Totals, ...	99·64	98·64	98·63

Four other examples may here also be given, on the authority of Clarke and Hildebrande, in Bulletin 148 of the United States Geological Survey (pp. 265, 275):—

TABLE of ANALYSES.

Constituents.	Formulæ.	I.	II.	III.	IV.
Silica, ...	ScO_2	21·19	3·94	9·34	7·05
Alumina, ...	Al_2O_3	·39	·64	·31	·48
Ferric Oxide, ...	Fe_2O_3	1·52	·43	·29	1·33
Ferrous „	FeO	-	·20	-	-
Manganese Oxide, ...	MnO	3·61	·61	-	·19
Lime, ...	CaO	35·61	51·96	50·01	50·08
Magnesia, ...	MgO	1·39	·52	·54	·57
Potash, ...	K_2O	-	-	-	-
Soda, ...	Na_2O	-	-	-	-
Water, ...	H_2O	3·09	·37	·13	·25
Phosphoric Anhydride, ...	P_2O_5	2·55	·50	·24	·27
Carbonic Acid Anhydride, ...	CO_2	26·84	40·71	39·11	39·68
Totals, ...	-	96·19	99·88	99·97	99·90

It is but just to add that most limestones contain quantities of phosphates varying from mere traces up to 0·1 per cent., as in Hodges' analyses given above. Complete series of detailed analyses of Irish limestone, are wanting; were such available, doubtless many specimens taken from the rock of the Central Plain would, in respect of richness in phosphoric anhydride, be seen to vie with those of which the analyses are given in the last table; though it may be admitted that the amount present in the first specimen in this table is unusually high.

Tax upon Soil Resources.

The tax upon the mineral resources of land, especially when grazed by store cattle, may be judged by the amounts cumulatively assimilated by different kinds of stock during growth and while fattening. A table is here given, taken from the Philosophical Transactions of the Royal Society (Part III., 1883, p. 1880),* setting forth the results of inquiry at Rothamsted regarding the demands upon mineral substances in fodder, for the sustenance and growth of various animals, and of weights as stated:—

---

* Paper entitled "Experimental Inquiry into the Composition of some of the Animals Fed and Slaughtered as Human Food," by Sir John Bennett Lawes, Bart., LL.D., F.R.S., F.C.S., and Joseph Henry Gilbert, PH.D., LL.D., F.R.S., V.P.C.S.

QUANTITIES, in lbs., of PURE ASH, and of each ASH CONSTITUENT, in the entire Animal, Fasted Live-weight (but Constituents of Contents of Stomachs and Intestines excluded).

—	Fat Calf.	Half-fat Ox.	Fat Ox.	Fat Lamb.	Store Sheep.	Half-fat Old Sheep.	Fat Sheep.
Fresh-weights, ...	258·750	1232·000	1419·000	84·406	97·625	105·063	127·156
Pure ash, ...	9·765	56·818	55·004	2·438	2·991	3·217	3·411
Iron Peroxide, ...	0·054	0·499	0·346	0·022	0·036	0·044	0·044
Lime, ...	4·257	26·026	25·428	1·082	1·291	1·418	1·505
Magnesia, ...	0·204	1·043	0·886	0·044	0·055	0·055	0·061
Potash, ...	0·533	2·521	2·496	0·141	0·170	0·177	0·189
Soda, ...	0·382	1·802	1·790	0·087	0·117	0·110	0·123
Phosphoric Acid,	3·969	22·668	22·015	0·950	1·161	1·259	1·322
Sulphuric Acid, ...	0·105	0·471	0·465	0·032	0·051	0·037	0·039
Carbonic Acid, ...	0·122	1·068	1·004	0·036	0·036	0·055	0·052
Chlorine, ...	0·162	0·730	0·782	0·045	0·070	0·053	0·056
Silica, ...	0·014	0·155	0·080	0·010	0·020	0·021	0·033
Total, ...	9·802	56·983	55·272	2·449	3·007	3·229	3·424
Deduct O = Cl.,	0·037	0·165	0·178	0·011	0·016	0·012	0·013
Total, ...	9·765	56·818	55·094	2·438	2·991	3·217	3·411

In their comments upon the results of the inquiry, as set forth in the above table, the authors point out (pp. 882, 883) that, as regards "the amounts of the most important mineral constituents, while 1,000 lbs. live-weight of calves and oxen may carry off from 30 to 40 lbs. of phosphate of lime, the same weight of sheep would carry off only about 26 lbs., or less. . . . . In round numbers it may be said that 1,000 lbs. live-weight of oxen will carry off only 2 lbs. or less, of potash; 1,000 lbs. of sheep 1¾ to 1½ lbs."

In the process of fattening the same authorities estimated (p. 883) that the increase of oxen and sheep, over the final four or six months of the fattening period, will not contain more than 1½ per cent. of mineral matter . . . . it may be stated in general terms that, of phosphoric acid, an acre would lose more in milk* and four or five times as much in wheat or barley grain, or in hay, as in the fattening increase of oxen or sheep."

A bullock removes from grass-land somewhat more than 9 lbs. of phosphoric acid annually, which represents about 5 lbs. per acre.

---

* The exhaustion of phosphate of lime in land was well illustrated some years ago in the case of the great dairying district of Cheshire. For its renovation dressings with crushed bones, and other mineral manures, was resorted to with success.—*Irish Farmer's Gazette* for July 14, 1900.

Green crops and cereals remove many times more than this quantity, which, in this case, viz., ground in cultivation, is rendered available by tillage and exposure. The deficiency which would consequently ensue is met by manuring, more usually in the case of tillage than in that of grass-land. Much of the grazing land in Ireland rarely, if ever, receives artificially-applied top-dressings, in which case vegetation is dependent upon the soils' natural resources.

How the Tax is Met naturally.

The loss in the feeding of store cattle, or even sheep, would obviously be very much greater than in fattening; all the lime and phosphates in the case, say, of the half-fat ox, in the table given, presumably come from the soil, and would be proportionately greater, weight for weight, in young stores. This class of stock, therefore, throws a great strain upon the resources of a soil. Apart from artificial compensation by manuring, the manner in which such heavy demands on land are met, the recuperative power of limestone soils, often shallow, may be illustrated in the following way. Let it be assumed that a film of limestone 1-100th of an inch in thickness, and containing ·1 per cent, of phosphoric anhydride (acid less water), undergoes solution in a certain period; or that an equivalent quantity of calcareous matter, of equal richness in phosphates, be leeched out of limestone fragments and particles, in a depth of, say, two feet of soil and subsoil; about 6 lbs. of anhydride per acre would be dissolved and supplied to the soil, or carried away, during that time—in quantity equivalent to nearly 50 lbs. of ordinary superphosphate.* Such a consideration goes far towards accounting for the continued high degree of fertility possessed by unmanured limestone land throughout Ireland, and for the unexhausted condition of shallow soils in many places, even where fed by store cattle.

Feed for Young Stock.

A further consideration as regards the rearing of young stock may here be presented, in regard to the proportionate amounts of mineral substances appropriated. Armsby, in his text book on "Cattle Feeding" (p. 149), gives a table setting forth results of experiments conducted by Soxhlet, at Vienna, with fodders supplied to a calf weighing 151·2 lbs., and directs attention to the large quantities of lime and phosphoric acid retained in the system, utilized chiefly in the formation of bone.

---

* Calculated from an analysis of mineral superphosphate given by Aikman (Johnston's "Agricultural Chemistry," p. 319), which contained 18 per cent. of monocalcic phosphate and 6 per cent. of insoluble phosphate.

MINERAL SUBSTANCES in FODDER, CONSUMED, EXCRETED, and RETAINED.

Substances in Ash of Fodder.	Grammes consumed (and grains.)	Grammes excreted in dung and urine.	Retained.	
			Grammes.	Per cent.
Phosphoric Acid, ...	25·34 (391 grs.)	6·53 (100 grs.)	18·81 (290 grs.)	54·30
Chlorine, ...	8·85	8·30	·55	6·22
Lime, ...	19·13 (295 grs.)	·38 (6 grs.)	18·75 (289 grs.)	98·00
Magnesia, ...	1·80	1·08	·72	40·00
Potash, ...	20·70 (319 grs.)	15·58 (240 grs.)	4·49 (69 grs.)	22·37
Soda, ...	5·57	4·16	1·41	25·31
Iron (? Oxide), ...	0·15	·10	·05	33·33

Armsby also further states (p. 145) that, according to the Weende experiments the daily fodder-maintenance of full-grown cattle contains of phosphoric acid, 0·05 lbs.; lime, 0·1 lb.; potash, 0·2 lbs.

Mineral Substances Appropriated.

Not only are lime and phosphoric acid retained in much larger proportion, and actual quantities, than in the case of any of the other substances, but the percentages of them appropriated from the quantities occurring in the fodders, are much higher than in the other cases. Thus the animal in question appropriated almost all the lime supplied, and considerably more than half of the phosphoric acid. It has been proved* that the proportions in which these essential substances exist in plants increases with the abundance in which they are present in the soil, within certain limits; soils, therefore, which minister lime and phosphates to vegetation most freely and abundantly, would, other conditions being equal, probably be best suited to the requirements of young stock, as tending to their better development. Ireland, as a whole, presents a greater proportionate area of limestone than any other division of the British Isles.

Irrigation.

It is almost needless to point out that the quantity of lime and phosphates set free annually by solution, as estimated above, in the case of limestone soils, is not all utilized by vegetation. A large proportion of such valuable nutrients disappears in drainage water; and it cannot be doubted that much of those and other fertilizing substances could be guarded from waste and conserved for the soils of Ireland by means of appropriate systems of irrigation (pp 70, 78). It is one of the means of wealth to which District Councils and co-operative bodies might advantageously direct their attention.

---

* Rothamsted Experiments, see pp. 14, 15.

Accumulations of Drift Material.

It will doubtless be asked, whence come the great accumulations of *débris*—clay, stones, &c.—particularly those studded with large blocks, and, therefore, known as boulder-clays, which are to be observed throughout Ireland, even after centuries, during which a large proportion of such superficial covering must have been transferred to the ocean, little by little, by means of streams and rivers? Much disintegration may reasonably be attributed to the grinding action of a slowly-moving thick mantle of land ice, which necessitates the supposition of transference of the products of attrition to considerable distances from their origin. Though there be much evidence to prove mingling of detritus, and transport also, to some extent, by the agency referred to, extensive transport of materials is not manifest in all cases when thick accumulations exist, but the contrary; and the large quantity of *clay* in many of the accumulations, as well as some other facts, go to prove that the Irish boulder-clays and kindred deposits are probably in part, perhaps chiefly, the result of long-continued *subaërial denudation* prior to, however much they have been moved and modified during, the Glacial Period.*

Plain of Marine Denudation

The natural processes, conveniently summed up in the term *subaërial denudation*, dissolve and carry off in invisible form, in solution, much of the solid material of the crust, notably of limestone, and leave the less easily dissolved shale, sand, and sandstone fragments, to mingle with the remains of incompletely disintegrated limestone. If the thickness of the original rock thus affected were sufficient—say, 1,000 feet or more—a large quantity of loose material could be accounted for. The only hypothetical elements in the case are a sufficient length of time, which may be assumed, and the depth of rock at the disposal of denudents. With respect to the latter point the conditions following the latest operations of *marine* denudation have to be considered; for in this process the comminuted materials resulting from coast erosion are carried out to sea, afar from land; and if the unsubmerged portion of the crust at any point, retained a constant level, with respect to that of the ocean bordering it, sufficiently long, a plain would result corresponding approximately with the ocean surface at low tide. This is known in physical geology as a plain of marine denudation. Sir A. Ramsay, a past Director-General of the Geological Survey, called attention to interesting evidence for the former existence of such a plain in Wales; and Professor Hull pointed out the probable former existence of plains of the same kind at high levels in Ireland.

---

* An interesting circumstance corroborative of the above conclusion is the occurrence of pieces of chert, which were once encased in limestone, in calcareous boulder-clays, far beneath the surface, where present percolating waters could not have caused their isolation, and severance from their former limestone matrix.

Subaërial Denudation.

When a sea-formed plain becomes elevated above the ocean level, subaërial forces—rain, frosts, atmospheric gases, wind, and running water—begin to operate, and progressively carve surface features into forms which at any period they present. It is a remarkable circumstance that the summits in the chief mountain groups in the four provinces, in other words, all around our island, do not rise much above, nor lie far below the level of 2,500 feet above the sea, in the northern half of Ireland, and 3,000 feet in the southern half. Thus—

1.	In the	Donegal	group,	Errigal	stands at	2,466	feet.
2.	,,	,,	,,	Muckish	,,	2,197	,,
3.	,,	Sperrin	,,	Sawel	,,	2,240	,,
4.	,,	Mourne	,,	Slieve Donard	,,	2,796	,,
5.	,,	,,	,,	Slieve Bingian	,,	2,449	
6.	,,	North Mayo	,,	Nephin	,,	2,646	,,
7.	,,	,,	,,	Slieve Cor	,,	2,369	,,
8.	,,	South Mayo	,,	Croagh Patrick	,,	2,510	,,
9.	,,	,,	,,	Mweelrea	,,	2,668	
10.	,,	Galway	,,	Formnamore	,,	2,239	,,
11.	,,	,,	,,	Bennabeola,	,,	2,336	,,
12.	,,	,,	,,	Benbawn	,,	2,395	,,
13.	,,	Leinster	,,	Lugnaquilla	,,	3,039	,,
14.	,,	,,	,,	Kippure	,,	2,473	,,
15.	,,	Magillicuddy	,,	Carrantuohill	,,	3,414	,,
16.	,,	,,	,,	Mangerton	,,	2,756	,,
17.	,,	Galtee	,,	Galtymore	,,	3,015	,,
18.	,,	Knockmealdown	,,	The Summit	,,	2,609	,,
19.	,,	Comeragh	,,	Knockanaffrin	,,	2,478	,,

These summits are formed of rocks of various kinds, Nos. 1, 2, 6, 7, 8, 11 and 12 being quartzite; 3 mica schist, 13 cleaved felsite* over granite; 4, 5 and 14, granite; 9 and 10 Silurian grits; and the last four of Old Red Sandstone strata. It cannot be regarded as a mere coincidence that hill summits, formed of rock of such different natures, could all range upon, or approximate to a plane; and it is therefore probable that in the summits of the mountain groups we have the vestiges of a great plain of marine denudation. It is possible that other such plains of marine origin, of more recent date, may have been formed at lower levels; but this is scarcely *probable*, since it would have to be supposed that the causes that produced them—the erosion of ocean waves and currents—left the outworks, the higher grounds around the island, unaffected; and this throughout the long period necessary for the formation of the plains within. If, then, no lower plains of marine denudation have been formed, the plane which we postulate, as passing through the highest summits, would leave a thickness of some 2,000 feet above the central plain of Ireland to be affected by subaërial denudation; in greater part, probably, this vast thickness has been carried off by rivers and glaciers, to be distributed over the ocean floor; and in part it remains in disintegrated form as detritus upon the present surface of the island. The sculpturing of the most massive and elevated hills proceeded concurrently with this local wasting of the crust.

---

* As recently ascertained by Mr. M'Henry of the Geological Survey.

The magnitude of such a conception may naturally deter many from accepting it, especially when the conviction is stated, that some, if not all, of our deepest valleys have been excavated since the Eocene epoch—the latest of which any records exist in Ireland, prior to the Glacial Period.* Of this, however, there can be no doubt, for, in the Mourne group, the granite which has been laid bare, and so deeply and extensively furrowed, is, in all probability, of Eocene † age; in Donegal, too, basalt dykes of the same age traverse hill and valley alike, of the Errigal group; and it is almost needless to remind the thoughtful reader that if the once-molten, but now solid rock, could have escaped from fissures at low levels in then existing valleys, it would not have risen, as has been found, to heights‡ which at present tower some 2,000 feet above the adjacent low ground.§ We have here, then, proof that subaërial denudation has wrought the great effects attributed to it, and within comparatively recent times, geologically speaking; there is, with this, strong justification for the inference that the low country stretching away from the foot of each mountain group named, has been brought to its present relative level, by the same cause as that which formed the valleys, rather than by marine denudation. An extension of the inference, only, is necessary, in order to understand how the Central Plain has been formed. This plain was once covered with Carboniferous strata, which lent themselves to comparatively easy disintegration. Wherever plateaux exist of minor elevation, or vestiges of such, as in the Benbulben region of North Fermanagh, the level form of the surface may be due to approximate horizontality of the strata, and the regular disappearance of layer after layer, of uniform degrees of solubility and disintegration; or, to former lake-erosion.

---

* Satisfactory proof is wanting that Pliocene strata exist, or have ever been deposited in Ireland.

† Formerly believed to be of Miocene age, see p. 110.

‡ A dyke of basalt was traced by the writer across the summit of Errigal (2,466 feet).

§ This argument for the vast amount of post-Miocene denudation (or post-Eocene, if we are to regard the basalts of Antrim of Eocene age, as some hold) is borrowed from Sir A. Geikie's work, "Scenery of Scotland."

The Central Plain.

It is remarkable that the highest ground in Ireland encircles the island, not very distant from the coast-line, and this circumstance enhances its attractiveness to the tourist. From his standpoint the country might be described as highly diversified, presenting a succession of rugged ranges, bare mountain tops, widely extending moors and solitary wastes; broad lakes, beautiful rivers, and picturesque valleys and gorges. The Central Plain presents a strong contrast to this—its low-lying, slightly undulating surface is monotonous to the passing observer; but viewed from the commanding summit of one of its few isolated hills it displays a degree of impressive grandeur. The accompanying Plate* (Fig. 28), fairly illustrates the wide-stretching level ground of the Plain.

River Denudation.

The hypothesis presented for the relative lowering of the central plain, with coincident moulding of the physical features throughout Ireland, finds confirmation in another remarkable circumstance, viz., that many of the rivers which drain the interior, find exit towards the coast through gorges and valleys in ridges and high ground. These, but for such openings, would form impounding obstructions to the drainage waters, often several hundred feet in height. Some instances may be mentioned, namely, the gorges of the Lee and Blackwater, in Cork; the gaps through which flow the Suir, at Waterford, and the Nore, at Thomastown; and those of the Collooney river, in Sligo, and the Owenmore, in Mayo. Much of the ground drained in such cases, occupies a lower elevation than the general summit-level of the ridges which are pierced by the outflowing waters. The natural, indeed, the only possible explanation, therefore, involves the supposition that the rivers assumed their main directions of flow when the present inequalities of surface did not exist, and further, that their erosive action maintained free exits, *pari passu* with the lowering of the land within. This, the reader will notice on the map, is mostly formed of Carboniferous strata which wasted faster, and thus declined more rapidly, than the

* From "Ireland, Industrial and Agricultural," p. 9.

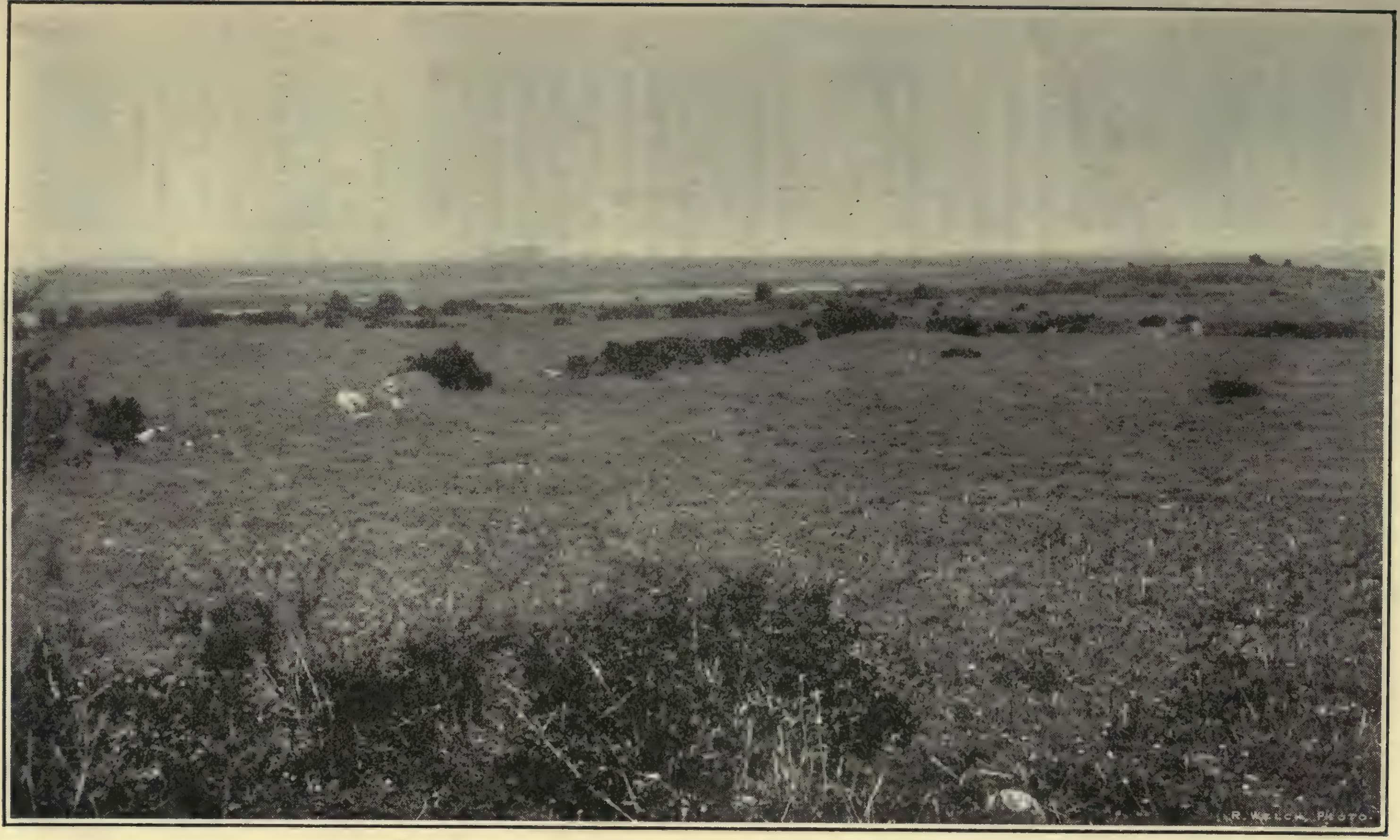


Fig. 28. View of the Limestone Plain, taken near Ballinasloe, Co. Galway.

areas of more unyielding rock outside, which now form the ridges and high grounds. On this hypothesis Prof. Jukes,* former Director of the Geological Survey in Ireland, accounted for the directions curiously taken by the first two rivers named above ; and more recently Prof. Hull, in his work on Ireland,† has thus accounted for the hollowing out of the gorge of the Owenmore, also mentioned above, and has discussed at length the physical history of the River Shannon.

The Shannon Gorge.

One of the most remarkable gorges formed in this way in Ireland, is that through which the Shannon flows, near Killaloe. The river here retains its southerly direction, notwithstanding that, south-westward by Scarriff, or south-eastward by Nenagh, it would find directions of outflow over ground not much higher than the surface level of Lough Derg,‡ as compared with the sides of the gorge through which it flows.

Throughout the ages occupied in the gradual lowering of the bordering areas, it has continued to carve its way through the Silurian and Old Red strata now forming the Slieve Bernagh and Arra hills, till the summits of its banks, towering above lake, river, and surrounding country, stand at elevations of 1,746 on the west side and 1,517 on the east, that of Lough Derg and the river itself being only about 108 feet above the sea.

In many instances river erosion has failed to keep pace with the lowering of the drainage areas within ; hence valleys and gorges are frequently to be met with, which no longer carry the main drainage of their districts, the water having found other directions of easier egress. Some striking examples are to be seen in the Ox Mountain range. Those of the Glen of the Downs, the Scalp near Dublin, Keishcorran in Sligo, and Barnesmore in Donegal, have been referred to by Prof. Hull.§

Hollows formed by Solution.

The denudation of the country has resulted not only in valleys in the more elevated tracts, but in hollows and unevennesses in the low ground, now wholly or in part filled with water ; or with peat, alluvial, or drift deposits. Sometimes these hollows are independent of any rivers which could be supposed to have excavated them, as those of Loughs Neagh, Derg (in Donegal), Sheelin, Owel, Ennell, and the Lakes of Killarney; and sometimes they lie along the courses of principal rivers, of which they are spoken of as enlargements, as Loughs Erne, Allen, Ree, and Derg. In all cases they are probably attributable in chief part to solution of the superficial rock, by waters charged with carbonic and *humus* acids. The very great extent to which rock immersed in such waters is affected, in comparison with the portions of the same exposed only to atmospheric influences, may be judged from the figure shown on p. 152. A hollow once formed on the surface, and capable of retaining water, tends to extend and become deeper, especially when the water is in contact with peaty matter and other decaying vegetation. Ice action during the Glacial Period may have contributed to the formation of lake basins, but there can be no doubt that solution has largely operated even since glacial times; eroded masses of the limestone shown in the figure just referred to, at Ballybay, occur as *blocks* placed there during, or possibly after, those times.

---

* Quart. Jour., Geological Society. Vol. XVIII., p. 397.

† Physical Geology of Ireland.

‡ About 135 feet in the former case, and 175 in the latter.

§ *Op. cit.*, 1st Ed., p. 182. Judging from the recently formed appearance of some of these gaps, it is probable, that to some extent they owe their origin to the voluminous floods issuing from the melting ice-sheet which covered those parts in Pleistocene times. This hypothesis has been invoked by Mr. Lamplugh to explain such gorges in the Isle of Man, and by Prof. Kendal, F.G.S., to explain similar features in the North of England—"Glacier-lakes in the Cleveland Hills." Quar. Jour. Geo. Society, Vol. LVIII., 1902. See also the Explanation of the recently issued Drift Map of the Dublin Area.

Scenic Features.

The effects of erosion accompanied by solution and disintegration, are strikingly exhibited in the hilly tracts, where the natural features are often of extreme grandeur. There also the attractiveness is enhanced by the difference of degree in which different kinds of strata have yielded to denudation. Thus, in the north-west of Leitrim and Fermanagh a succession of deep valleys has been carved out of a tableland, the levels of which, as now indicated by the summits of ridges, stand some 1,500 feet above the lowest parts of the valleys. A section across those ridges (Fig. 29)* will exhibit the physical geology of the district. The hills consist for the most part of earthy and freely weathering limestone, capped by more enduring limestone and sandstone, which accounts for the precipitousness of the escarpments. Here, amongst the Benbulben group of hills, the observer beholds a succession of ridges, bounded by steep-faced, faintly terraced escarpments, extending westward; the ridges terminate in striking headlands, which descend to the plain in rapid descents and graceful curves, and overlook the ocean a few miles distant. The character of the scenery is illustrated somewhat feebly by the accompanying print (Fig. 30).†

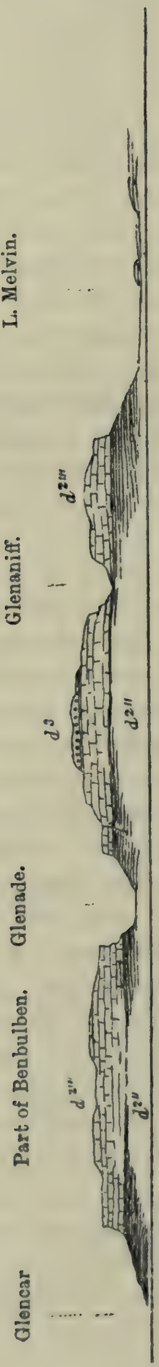
The same character of scenery is continued southward into Sligo, in the country lying to the north of Lough Gill, and is reproduced on an impressive, though less attractive scale in the region between Loughs Allen and Erne.

---

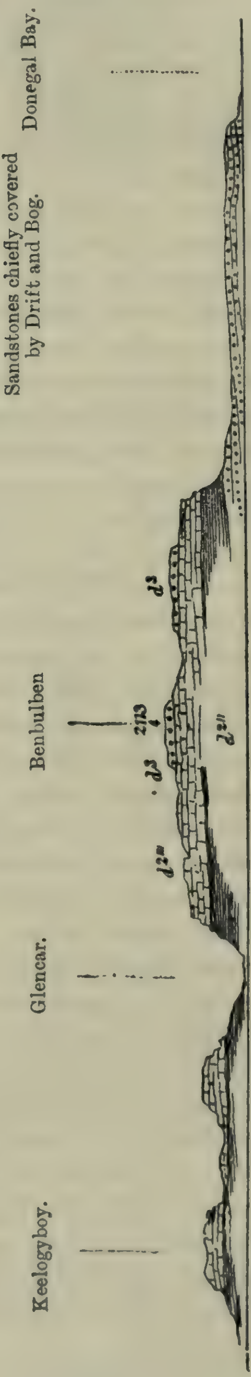
* Taken from Explanation of Sheets 42 and 43, p. 31.

† From Explanation of Sheets 42 and 43.—Frontispiece.

The Burren district of Clare is notable for scenery of a peculiar



Sketch Section across Glenade and Glenaniff.



Sketch Section across Benbulben.

Fig. 29. Horizontal Sections to illustrate the Physical features and Geological structure of North Leitrim and Sligo.

character, unique in Ireland. Wide stretches of bare limestone there prevail, trenched with gaping crevices, deep gorges, and valleys separating terraced hills, the *pseudo*-artificial appearance of which, combined

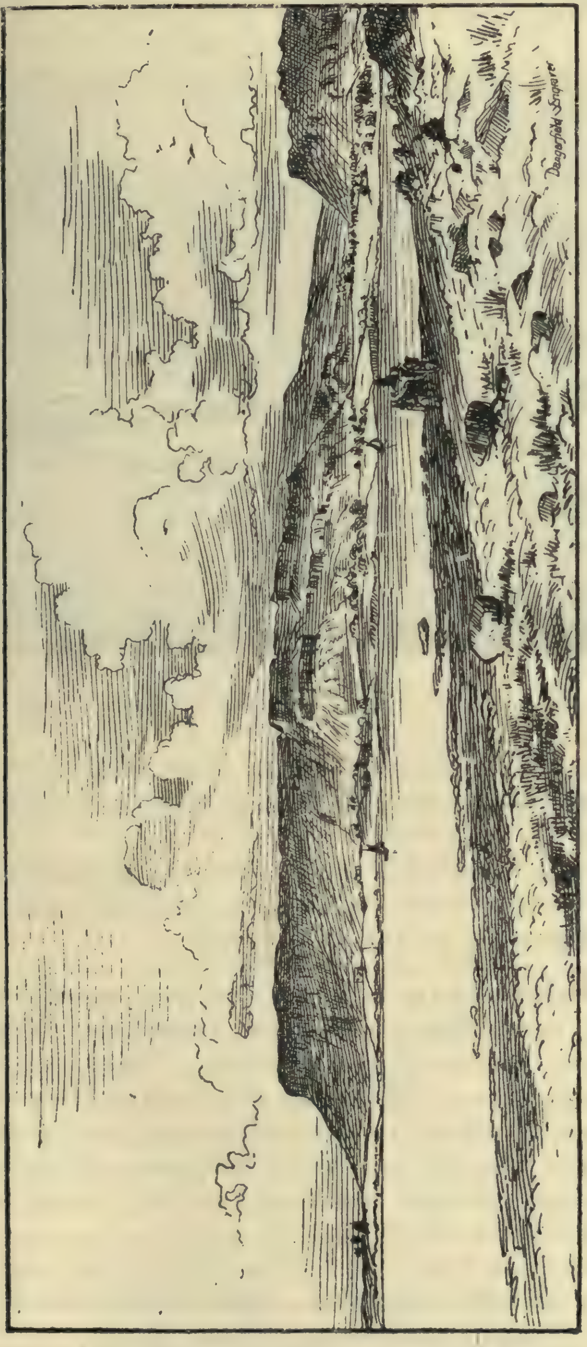


Fig. 30. Benbulben from Finisklin, looking across Sligo Bay.

with the unusual sterility of the region, impresses the beholder with a sense of weird desolateness. Figure 31 presents a characteristic view of the region.

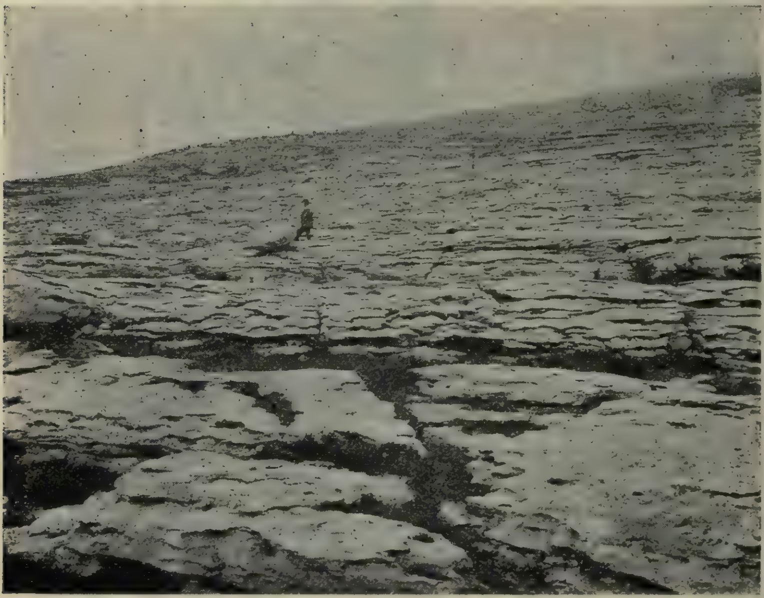


Fig. 31. Terraced Limestone characteristic of the Burren District of Co. Clare.

The limestone series, usually divided into Lower Limestone, "Calp," and Upper Limestone, possesses an aggregate thickness of some 2,500 to 3,500 feet.

Professor Hull * gives 2,500 to 3,000 feet as the greatest thickness of the limestone series, which is somewhat less than that estimated by Mr. G. H. Kinahan † in the County of Limerick.

Upper Series.—This series includes strata which correspond in age and character to those known in England as Yoredale Shale, Millstone Grit, and Coal Measures, in ascending order. Though these strata cover an aggregate area of 2,523 square miles in Ireland, they are not of such a degree of interest, in an agricultural way, as to justify an extended notice here. The soils derived therefrom are of an unpropitious character, somewhat resembling those derived from Lower Carboniferous Sandstone and Shale.

The strata of the Upper Series are, moreover, for the most part unfavourably situated for agriculture, usually occupying the highest grounds in the Carboniferous area. This not only renders access difficult, and necessary field operations expensive, but, lying so high, these strata are largely devoid of drift, and with it of the amelioration which drift materials usually impart.

---

* "Physical Geology of Ireland," 2nd ed., page 50.

† "Geology of Ireland," page 71.

Irish Coal-fields.

In concluding this account of the Carboniferous System the following facts may here be mentioned relative to the Irish Coal-fields. They are, as already mentioned, of small aggregate extent, notwithstanding the unfounded impression which has long been, and is still abroad, that coal exists in every hilly tract—an impression which has betrayed some into useless expenditure.

Profitably workable coal seams are confined to areas in Antrim, Tyrone, Queen's County, Kilkenny, Tipperary, and Leitrim. It should be noted that in most, if not all, of these places the best seams have been worked for many years; and the coal which remains can now be obtained only at an expense which places Irish coal at such a disadvantage, in competition with the better English and Scottish coals, that little outside a local trade has of late been tried. With lowered railway freights, and more approved methods of working than those hitherto practised in certain parts of the coal areas, a better trade might be done. An attempt to work the Coal Island seams on a good system, by means of a deep shaft, some 28 or 30 years ago, proved abortive. It is believed that much coal lies concealed beneath the New Red Sandstone near Coal Island, but the risks involved have hitherto deterred investors. The "net tonnage available" in Irish coal-fields in 1881 was 182,280,000 tons, according to Prof. Hull*; and of such a stock only 125,000 tons are yet raised annually. The Royal Commission on the coal supply, appointed in 1870, reported 146,480 millions of tons available, for Great Britain, down to a depth of 4,000 feet. The yearly rate of consumption was upwards of 113,000,000 tons in 1871, with a yearly increase of 3,000,000 tons. In 1902 the output for Great Britain was 227,000,000 and for Ireland 108,737 tons. The output in Britain is therefore very much greater than that in Ireland, proportionately to their respective supplies; so that although the coal deposits are unfortunately diffuse, the mineral occurring in thin seams difficult and expensive to work, there is considerable room for coal-mining enterprise in this country.†

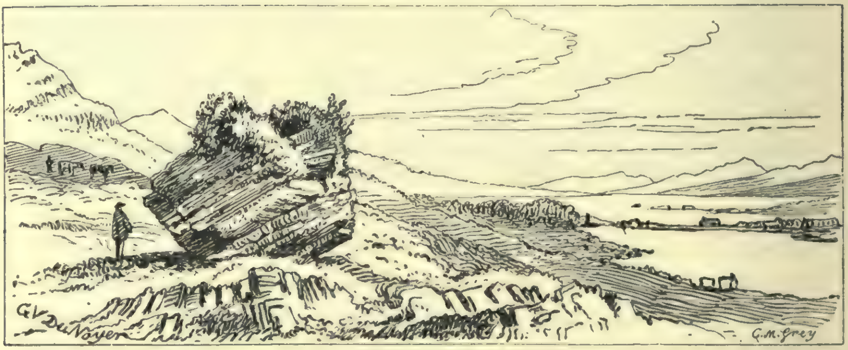
---

* Coal Fields of Great Britain. E. Hull, M.A., F.R.S., *3rd* Ed. Recent investigation has proved that the Kilkenny coal-field possesses a much wider extension than Professor Hull reckoned upon.

† Important extensions in the boundaries of the Ballycastle and Castlecomer coal-fields have recently being made during a re-survey of the districts by Mr. A. M'Henry of the Geological Survey—Director, Professor G. A. J. Cole, M.R.I.A.

Fire-clay.

Fire-clays are usual components of the Coal Measures, being found beneath the coal seams, and associated with sandstone and shale. The substance occurs in quantity and of excellent quality at Coal Island and Annaghone in Tyrone; it is also to be found near Arigna Ironworks, in Roscommon; in the Leinster Coal-field in Kilkenny and Carlow; and in the coal-field which extends over parts of Clare, Limerick, Kerry, and Cork.



Boulder of limestone called "Cloghvorra," S. side of Kenmare valley, showing "the sound" at Kenmare, and in the distance the mountains near Sneem.[*]

From Explanation of Sheet 184, page 36.

CHAPTER XI.

NEWER FORMATIONS.

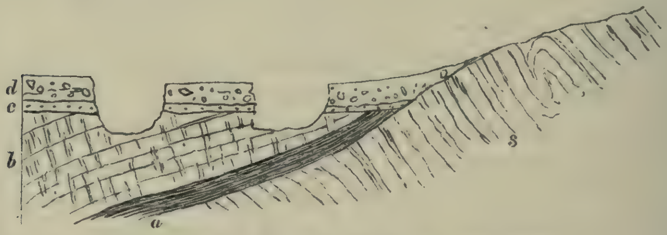
PERMIAN, TRIASSIC, JURASSIC, CRETACEOUS, MIOCENE.

All the systems known under the above names, with the exception of the Permian, belong to the Mesozoic or Secondary Age; and all, including the Permian, occur in the North-east of Ireland. They are indeed confined to Ulster, except in the case of one small area of Triassic strata, which occurs between Kingscourt and Carrickmacross.

PERMIAN FORMATION.—The only recognisable Permian strata in this country are to be found in three localities, all in the Province of Ulster. At these points they occupy insignificant areas, not four square miles in the aggregate. The city of Armagh in part stands on one of the patches, where the rocks consist of some 17 feet in thickness of red breccia and conglomerates, resting unconformably upon Carboniferous strata. Upon the breccias, &c., reposes a boulder bed—also of Permian age, containing blocks of grit and quartzite, and closely resembling a modern boulder-clay, as may be seen in a quarry to the west of the city. South of Belfast Lough, a small deposit of Permian dolomite and marl occurs, the dolomite of which was formerly utilized in the manufacture of sulphate of magnesia. Two other small patches exist, one on each side of the village of Grange, south-east of Cookstown, where yellow and flesh-coloured dolomites similar to the above are found. These dolomites weather like sandstone, and, as is common with this class, contain cavities lined with crystals. A specimen of the dolomite, or Magnesian Limestone, at Holywood, analysed by Dr. Hodges, gave the following constituents:—

Carbonate of lime, . .	46·33
Do., magnesia, . .	44·11
Phosphate of lime, . .	·31
Oxide of iron and alumina, .	2·25
Silica and clay (insoluble), .	5·00
	98·00

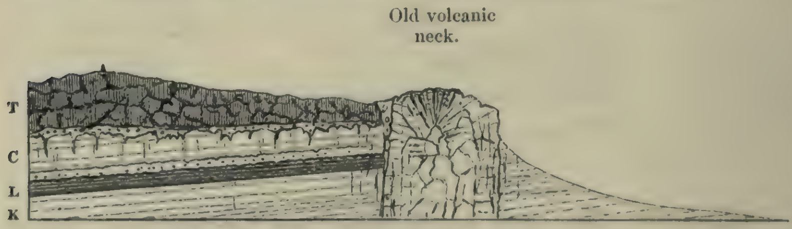
TRIASSIC SYSTEM.—New Red Sandstone and New Red Marl.—Rocks of this system appear at several points on the outskirts of the great basaltic area of Antrim and Londonderry. They crop out almost continuously along the base of the escarpment which forms the eastern coast line: inland, too, they form three considerable areas—chiefly in the low-lying country—namely, a tract drained by the Lagan and some of its tributaries which extends eastward through North Down as far as Strangford Lough; another spreading out east and west of Benburb in the low-lying tracts drained by the Blackwater and Callan rivers, and extending by Dungannon as far as Coal Island; and the third to the east of Limavady. The system, as represented in this country, consists of two members—a lower, composed chiefly of sandstone; and an upper, of marl; and its basal beds rest unconformably upon older Formations, viz.—Metamorphic, Silurian, and Carboniferous. The relation of Triassic rocks to Carboniferous strata is shown in the following woodcut (Fig. 32*), which indicates two unconformabilities; one, that just mentioned, and the other, that of the Carboniferous strata upon Silurian.†



s Lower Silurian grits, &c., highly inclined and contorted.
a Reddish and Blue Shales, at base of Limestone.
b Carboniferous Limestone. *c* New Red Sandstone. *d* Boulder Clay.

Fig. 32. Section in Limestone Quarry at Castle Espie, Co. Down.

In the Londonderry area the marl crops out along the foot of the basalt escarpment and overlies the sandstone, the latter appearing in a wide band, much concealed by Drifts, south-eastward of Limavady. In the South of Antrim the succession of strata is to be well seen. It is represented in the second illustration here shown (Fig. 33‡), in which the position of the overlying Formation is also indicated.



T Lower basalt. L Lower Lias.
C Cretaceous beds. K Keuper marls.

Fig. 33. Carnmoney Hill, Co. Antrim.

---

* From Explanation of Sheets 37, 38, 39; p. 37.

† It may be mentioned that the data represented in this section are not well attested.

‡ From Explanation of Sheets 21, 29, p. 30.

New Red Sandstone.

The Lower Series contains red and orange-coloured sandstone, sometimes mottled and yellowish. It is frequently marly, and occasionally the beds show ripple markings, rain-drop pittings and sun-cracks, and footprints of long extinct animals—all vividly recalling the conditions of common observation, under which similar aqueous rocks are formed in the present day. Interesting fish-remains occur in the strata of the tract lying to the south of Dungannon. The area already mentioned, near this town, consists of the lower member; which also margins the Lagan, chiefly on its north side, between Lisburn and Belfast Lough. The sandstone is also the member which forms the eastward extension to Strangford Lough, and yields building-stone as in the quarries at Scrabo Hill.

New Red Marl.

The Upper Series, consisting of marl, is to be well seen in the railway cutting along the Belfast and Larne Line. It occupies an area nearly two miles in width, on the north side of Belfast Lough, and there contains irregular beds of gypsum and seams of rock-salt, which has long been mined, at some distance to the north of Carrickfergus. It extends south by west in a narrow strip along the foot of the escarpment which bounds the Lagan Valley, on the west side; also crops out along the coastline northward; and, as above stated, forms a tract in Londonderry, to the east of Newtownlimavady. The small outlying area at Carrickmacross, consisting of marl, contains gypsum.

The unweathered marls contain a considerable proportion of lime carbonate, as do boulder-clays derived chiefly from them. A few estimations of this substance, in three samples of marl, gave to the writer the following results, viz. :—

	Per Cent.
Ordinary marl (red calcareous clay) ...	22·27
Strong bed of red marl, in the clay ...	31·00
Strong bed of green marl, in the clay ...	50·16

The soils formed from the "Sandstone" are mellow sandy loams; while those from the "Marl" are usually stiff clay-loams. Frequently, however, the latter are ameliorated by their containing a proportion of fine sand derived from the originating rock. The soils contain very little carbonate of lime in the uppermost foot or eighteen inches.

Trias of the Continent.

A remarkable correspondence exists between the lowermost and uppermost members of the Triassic Formation on the Continent and the members just described, though the middle one—the *Muschel-*

kalk of Germany—is absent in Ireland. The lowermost is formed of red and variegated sandstones; and the uppermost of marls, with beds of rock-salt and gypsum. Differences in detail doubtless exist, which lessen the value—for purposes in Ireland—of analyses carried out on the Continent of either the Triassic rocks or the soils derived therefrom. Three, however, are given from M. Risler's standard work.

In Vol. I., pp. 202, 216, are given from M. Grandeau, the compositions of "two earths formed by the Vosges sandstone—the first, earth of forests of the Mossegthal (Alsace); the second, cultivated and manured earth of Angomont (Moselle)"; and of one (No. 3), after "Keuper" (marl).

—	No. 1.	No. 2.	No. 3.
Water, ...	1·80	1·62	5·40
Combustible Matters, ...	3·20	4·12	9·40
Alumina and Oxide of Iron, ...	0·46	1·48	3·55
Lime, ...	0·02	—	0·18
Magnesia	0·02	0·27	0·21
Potash, ...	0·03	0·09	0·19
Soda, ...	0·06	0·06	0·09
Phosphoric Acid, ...	0·02	0·09	0·07
Residue insoluble in Acids, ...	94·42	93·00	81·58
Totals, ...	100·03	100·73	100·67

The soils, both sandy and marly, contain little lime or phosphoric acid, and a considerable proportion of oxide of iron (giving the red colouration in the insoluble part of each sample).

JURASSIC SYSTEM (Lias, with which is here grouped the underlying Rhætic Beds).—Although in a geological point of view interesting, as representing an important English series, these rocks contribute very little to the aggregate of Irish soils. They may, therefore, be dismissed with brief reference. Together with the overlying chalk, they form the escarpment which encircles the basaltic plateau.

The Rhætic Beds consist of red, green and gray marls, which are but slightly calcareous, dark bluish arenaceous shales, and limestone. In Collin Glen they and the Lias may be well seen; and here the former contain a greenish calcareous sandstone which is considerably phosphatic.

The Lias does not differ very widely in character from the foregoing, consisting of blue clays and black indurated shales, with blue marls and dark limestone. It occupies an insignificant area appearing mostly in sections, in Woodburn Glen, along the Coast by Larne northwards, and at Portrush.

CRETACEOUS SYSTEM.—In attempting to harmonize the English and Irish geological classifications, account must be taken of a long lapse of time, during which deposits were in process of formation in the English area, namely, Oolitic, Upper Jurassic, and Lower Chalk strata, which have no representatives in North-east Ulster nor elsewhere in Ireland : this is the more curious when, as is shown in the last woodcut (p. 176), an apparently unbroken succession exists here.

The lowest Cretaceous rocks in Ireland correspond in position, and in most respects in character, to the Upper Greensand of England. They consist of calcareous and non-calcareous beds, sandstone coloured deep green with numerous particles of silicate of iron, alumina, potash, &c., and are therefore described as *glauconitic*. Their thickness varies from 70 to 80 feet near Belfast, to a few inches in North Antrim; and they also vanish southward. The upper beds are mottled with green, and may best be connected with the Chalk above ; they are also generally pebbly and occasionally conglomeratic, and are known as "Mulatto Stone." Overlying this somewhat remarkable deposit comes——

Chalk, a hard, white, compact limestone, contrasting strongly in texture with the deposit in South-east England, from which the name is taken ; the English deposit is quite soft. Like the English (Upper) Chalk it contains layers and nodules of flint, the nodules sometimes being of very large size. Its thickness beneath the basalt near Belfast has been estimated at 50 to 100 feet.

The small space which this Formation occupies has been remarked upon above. In two places, however, where the basalt has been denuded and the Chalk escaped denudation, it forms areas which, though not considerable, may be noticed—one around the town of Lurgan, the other lying to the north-east of Stewartstown. In both places the rock is much concealed by Drifts.

TERTIARY GROUP.—The basaltic rocks of Antrim, which in themselves form an important series, give a place in the geological record to the Irish Tertiary group, which otherwise it would not possess. The descriptions of these rocks must, however, be postponed to a future page, to maintain their lithological connection with others of the basic igneous class, and because of their agricultural value. Treatment of the group will here, therefore, be confined to a comparatively insignificant series of sedimentary deposits, intervening between the successive layers of basalt. They consist of seams of clay, leaf beds, ores of iron, bole, lithomarge, ochre, and pisolitic iron ; and with these occurs bauxite, a valuable commercial commodity, because containing 52 to 67 per cent. of alumina, to 11 to 20 per cent. of silica—a much greater proportionate quantity of alumina than is contained in ordinary silicates of this substance (see Table on page 112).

These deposits, and the igneous rocks associated with them, have been regarded, by the members of the Geological Survey, as of Miocene age. Mr. J. Starkie Gardner, F.L.S., G.S., &c., however, concludes from a detailed study of the abundant plant remains, found in the so-called "leaf-beds," that it is more in accordance with the present knowledge of Tertiary flora to assign the basalts and intermediate beds to Eocene age.*

Lough Neagh Clays.—An important deposit of gray, purple, and blue stiff clays, containing layers of sandstone and lignite, occupies a considerable low-lying tract adjoining Lough Neagh on the south. It is estimated to be some 500 feet in thickness, and seems to have been laid down, as a delta, from waters entering a former expansion of the lake. The relations of the "clays" to the glacial Drifts are obscure. In the belief that the latter are more recent than the clays, Professor Hull considered the deposit to be of Pliocene age; but the fossil evidence for his conclusion is, unfortunately, not satisfactory; a few sections reveal certain plant-remains, which would seem to indicate that the deposit is of more ancient date than Pliocene—the same age as the inter-basaltic beds, that is, Eocene. Pieces of silicified wood also occur (?) in the clays, which appearance has given rise to the supposition that the waters of Lough Neagh possess petrifying properties.

Economic Uses.

At Coal Island, near Dungannon, the clays have been used in the manufacture of coarse pottery. The purity and homogeneous character of this deposit, the presence of pure Carboniferous limestone near Coal Island, inexhaustible quantities of these materials, good coal supply if satisfactorily worked, abundance of water, and a convenient canal service in connection with so large and important a population-centre as Belfast, all combine to render the district an ideal one for the establishment of a profitable cement industry. To other advantages may be added that of unlimited supplies of flints from the chalk of the region, which, when roasted, furnish a desirable auxiliary.

An excellent cement has been made, by Henry Reid, of London, with limestone and decomposed basalt, supplies of which occur in the neighbourhood of Coal Island. Reid, in his valuable work, "Portland Cement, its Manufacture and Uses" (pp. 31 to 119), gives analyses of clays, limestones, flints, and other materials which might be matched by those of corresponding substances in this and other Irish localities. Special analyses of the local materials would, of course, be required were an industry contemplated. Enterprise in this direction is at present feebly represented in this country, though the field for it is sufficiently wide to justify large capital outlays.

---

* *Quar. Jour. Geo. Soc.*, vol. xli. (1885), p. 82.

Economic Minerals in Ireland.

The meagreness of mineral wealth in Ireland is well known. With regard to coal supplies, figures have already been given (p. 173) which show that this country's endowment is scarcely *one-eight-hundredth* part of that which Great Britain can boast. The workable Irish metalliferous ores also show a great disparity; if we estimate them by the outputs, Ireland is only one hundred and thirty-eighth (in weight), and one two-hundred-and-twentieth (in value), as favoured as the sister island; and though ores are present probably in large quantities, they are diffusely distributed, a circumstance which is prohibitive of profitable mining in by far the majority of instances.

Gold is believed to occur in large quantities in the Croghan-Kinshelagh and Ovoca districts of Wicklow. According to Mr. G. H. Kinahan, it has been found at some thirteen different points in Wicklow, as well as at Slieve-an-Orra in Antrim, St. Mullins in Carlow, Carrigacat, and Kilcrohane, in Cork, Ballinascorney and Rathfarnham in Dublin, Knaderlough in Donegal, Moyola River in Londonderry, Liffey and Slaney Valleys in Wicklow and Kildare.

Tin also occurs in the gold-bearing gravels of Croghan-Kinshelagh region, at Woodenbridge, and in a lead-vein at Dalkey.

Silver, Lead, and Zinc have been obtained, sometimes together, in Glenmalure and Glendalough, Co. Wicklow; Silvermines, in Tipperary; at Finntown, near Gweedore, and other places in Donegal. The ores of these metals are widely disseminated in Ireland, though in very minor quantities; they have been reported from some 342 places, distributed throughout thirty counties; and have been mined at many points, at almost all of which the ores are said to be worked out.

Copper, at Ballymurtagh and Knocknamo Hill in Wicklow; Knockmahon and Bunmahon in Waterford; Berehaven, Kilcrohane, Ballydehob, Skull, Crookhaven, and Roscarberry, in Cork; and at some 280 other places in Ireland, at almost all of which points the quantities are trifling, many of the larger supplies being "worked out."

Iron.—Ores of this metal are widely distributed; it occurs in nodules and nodular beds of "ironstone" in the Arigna district of Leitrim; the quality of this ore at Creevalea, in that district, is excellent, and smelting has been carried on to some extent. Three centuries ago ironstone appears to have been smelted at Drumard, near Draperstown. Various forms of iron ore already mentioned occur between the "sheets" of basalt in Antrim. It has an annual output of about 81,000 tons. Iron ores, both in veins and interbedded with rocks, are of common occurrence, though not remunerative.

Bog Iron Ore will be referred to later on (page 229).

Manganese, Antimony, Arsenic, Cobalt, Nickel, Titanium, Molybdenite, and Graphite have also been found in noticeable though unremunerative quantities.

Pyrites occurs in many places, and has been mined as a source of sulphur in the Lead mines and Copper mines of Wicklow, Galway, Cork, Mayo, Tipperary, and Donegal.

Bauxite, yielding 52 to 67 per cent. of alumina,* and valued as a source of the metal aluminium, is obtained near Ballintoy, in the Co. Antrim. It sells at nearly 6*s.* per ton, and in 1902 about 9,000 tons were raised.

Steatite, or soap-stone, occurs in the metamorphic rocks, chiefly in association with limestone bands; and some, of economic value, has been obtained at Crohy Head, and at Garton, in the Co. Donegal.

The supplies of most of the above minerals have either been exhausted, or run to such an extent, that the output can no longer afford a margin for profit, after paying working expenses.

---

* The following Table, drawn from "Metal Mining," by G. H. Kinahan, M.R.I.A., *Scien. Proc. Roy. Dub. Soc.*, p. 262, and "Mineralogy," by Collins, p. 263, gives the proportions in which the essential constituents occur in the chief economic hydrosilicates, including *Bauxite*, and Kaolin (varieties, pipe-clay, potters' clay, lithomarge).

—	Kaolin,	Alumite.	Wecheinite.	Bauxite.
	per cent.	Per centages.	Per cent.	Per centages.
Aliumina, ...	41·2	42·45—52·37	57·01	35·19—67·83
Silica, ...	48·0	27·50—13·15	19·60	21·47—10·64
Iron (Fe_2O_3), ...	—	1·54—1·29	1·08	3·72— ·47
Lime, ...	—	0·46—0·48	4·83	5·30—5·26
Magnesia, ...	—	traces.		
Potash Soda, ...	—	0·01—0·06		
Acids, &c., ...	—	9·48—5·55		
Water, ...	10·8	18·53—27·13	17·45	16·32—15·80
Total, ...	100·0	100·00—100·03	100·00	100·00—100·00

Barytes is widely distributed, and occurs in workable quantity near Bantry; at Mount Gabriel, near Schull; at Duneen Bay, Clonakilty, Co. Cork; and at Gleniff, near Bundoran, in Donegal. It also occurs at Ballydehob, in Cork; Glenmalure Mines, in Wicklow; and at several other points in Ireland, but in small quantities.

Gypsum occurs in the Triassic rocks near Belfast and Kingscourt.

Rock Salt also exists in these rocks, and has already been mentioned (see p. 107).

Slate.—Some quarries of Irish slates have also been mentioned (p. 67). Neither in respect of these, nor of other mineral products, does the present book profess to afford exhaustive information. What is aimed at is briefly to illustrate the character of the country's natural resources. Readers who desire full information will find it in "Economic Geology of Ireland," by G. H. Kinahan, M.R.I.A., who gives an elaborate account of the metal mining, slate, clays, and building-stones. Recourse has been had to this source of information for the localities of many of the economic clay deposits, given in Section III.

Columnar Basalt over Pisolitic Iron Ore, Cloonetrace Mine.*

* From Explanation of Sheet 20, page 14.

CHAPTER X.—IGNEOUS ROCKS.

ACID GROUP.

The principal rock of this group is Granite, of which there are several large areas to be met with throughout Ireland. It generally forms high grounds—the cores of great mountain groups—which usually show dome-shaped and occasionally serrated outlines. It also occupies large expanses of low-lying rocky wastes.

The principal areas are those which form:

1st. The central portion of the Dublin and Wicklow mountain range;

2nd. The Derryveagh and Glendowan mountains of Donegal, and an adjoining low-lying tract;

3rd. The southern half of Connemara;

4th. The core of the Ox Mountains in Mayo and Sligo;

5th. Slieve Croob and the adjoining tract which extends south, westward by Newry.

6th. Slieve Donard group in Down.

Many smaller areas of granite occur in proximity to the larger tracts, and if the reader recall the mode of occurrence of igneous rock, as described and illustrated on a previous page (p. 51), he will understand how the granite of the smaller areas may be regarded as coalescing beneath, with that of the larger, denudation not having proceeded so far as to reveal the connection. Owing to the same cause also, many patches of sedimentary rocks lie superficially embedded in the granite, showing that the former rock originally extended over the area where granite now prevails. Many instances of such outlying patches, both of schists and limestone, and of quartzite, occur in the granite between Dunlewy and Crohy Head, near Dungloe in Donegal; and between Rathdrum and Baltinglass in Wicklow—the summit of Lugnaquilla being formed of such an outlying patch of felsitic schist.

Ages of the Granites.

The ages of the different granites of Ireland involve interesting geological questions, which cannot be discussed in the present work; it may be mentioned, however, that the granites of Donegal, Slieve Croob, and Leinster are believed to be of the same age. Those of the Ox Mountains and Galway invade metamorphic strata; and were intruded prior to the Carboniferous epoch, as were the former three masses; so that there is no reason for disbelieving that all the masses named are of Old Red Sandstone age—corresponding, as they also do, in general character.

The granite of East Ulster, which forms the Slieve Donard tract, differs, as regards appearance and composition, from those above mentioned; and though occurring in close proximity to that of Slieve Croob, is of much more recent age. Dr. Haughton described it as containing albite in addition to quartz, mica, and orthoclase. It contains numerous small cavities which are often lined with crystals of smoke-quartz, orthoclase, and topaz; even those of emerald have been found therein.

This granite cuts off certain basalt dykes, which penetrate, and are therefore newer than, the Slieve Croob granite; and this fact constitutes distinct evidence that the former is much the newer rock.*

The scenery afforded by the Mourne granite is illustrated in the accompanying view (Fig. 34),† the highest summits in which are formed of this rock. The configuration of the country, as thus shown, indicates that the question of soils yielded by the granite of the area, need not detain the reader. The composition of the rock is given in the table of analyses, p. 120.

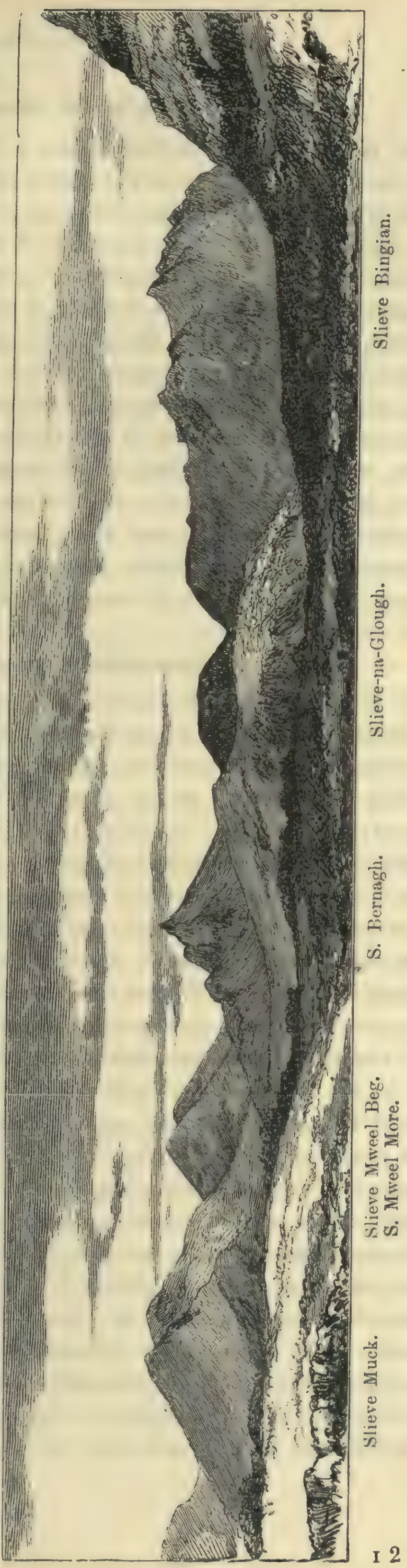

Slieve Muck.
Slieve Mweel Beg.
S. Mweel More.
S. Bernagh.
Slieve-na-Glough.
Slieve Bingian.

Fig. 34. The Mountains of Mourne from the vicinity of Hilltown, looking S. and S.E.

---

* Its age in geological time is given as Tertiary in "Ancient Volcanoes of Great Britain," by Sir A. Geikie, D.C.L., F.R.S. Vol. II., p. 421.

† From Explanation of Sheets 60, 61, 71.—Frontispiece.

Banding in the Granite.

The older granitic rocks often display a banded and foliated structure, as may well be seen in the granite of Donegal. The banding seems to be due to some slight difference either in the composition of the adjoining bands, or in the mode of their crystallization. The foliation has been caused either by the compression of the mass after solidification, or by slight movements of it during its solidification: in whichever circumstance the cause operated, the crystalline components have been arranged ("orientated") in certain definite directions. When foliation is manifestly irregular and extreme, the rock becomes a gneiss; and while some rocks of this type may be classed with mica-schists, others may preferably remain associated with granitic rocks. Coarse granitoid gneisses occur with the granite of the Ox Mountains, at Erris Head, at Belmullet in Mayo, and at Carnsore in Wexford; and much of the gneiss already mentioned as occurring near Ballyshannon, and to the north of Pomeroy, is of a granitoid character

Granite Disintegration.

On weathering, granite breaks up into large angular blocks; occasionally it assumes a bedded-like or platy structure; but in either case it forms a rugged surface in disintegrating. The felspars, oligoclase and orthoclase, sometimes albite, are attacked by the acidulated water of the atmosphere; carbonates of potash and soda are formed, and a residuum of hydrated silicate of alumina is left, which is known as kaolin. Weathering of this kind may proceed to a great depth, forming a mass which can easily be dug with a spade; so friable indeed that the kaolin may be removed by drenching with a water-hose, as near Penzance in Cornwall. The micas also give way to solvents in the process of weathering, and yield carbonates of potash, magnesia, and iron: and the quartz, deprived of its cementing substances, is left as sand in the detritus—this sand itself breaking up into still finer material, a process accelerated, as suggested by Risler, by the microscopic liquid and gaseous cavities, which the quartz of granites usually contains. The disintegration of granitoid gneisses proceeds in a similar manner. Thus, a granite-soil or gneiss-soil, ultimately formed, would be aluminous or sandy in proportion as felspar or quartz predominated in the originating rock. So greatly does felspar resist ultimate decomposition, that the resulting "clay" largely consists, in usual cases, of felspathic mud. The quartz too may break up into extremely fine sand, which when wet may be almost as unctuous and tenacious as clay; the difference, however, is apparent in drying, for clay remains strongly intact, while the fine sand and felspathic mud become friable,

Soils after Granite.

Most of the granite areas are sterile, or comparatively so, except where the occurrence of a drift covering modifies or conceals the soil characters to be expected from the decay of the underlying rock. Where the granites are above the levels at which the drifts occur, they are usually covered with peat or a scanty coat of gravelly soil; and even in low-lying ground, as in South Galway and the country around Dungloe in Donegal, a peaty covering is most common; yet that which in those parts presents (on reclamation) the most favourable agricultural conditions. In Carlow, however, and generally on the gentle slopes of the Down and Leinster hills, much favourable soil is to be met with, which consists almost wholly of granitic detritus. The granite in the higher grounds is often visible as bare, bleached rock, which, contrasting with the adjoining peat-covered ground, enhances the scenic effect; and the features usually display themselves in imposing array in Donegal, Down, Dublin, and Wicklow. It is rarely that the detritus of this rock, descending from and skirting these hills, forms fertile soils, because of its coarseness. It contributes, however, towards the fertility of the soils with which it commingles. Potash is the chief plant-food supplied by granite, but this it yields up slowly. Lime and soda also are to a certain extent supplied, especially where oligoclase exists in the granite in considerable quantities, as in some of the granites of Donegal.

The corresponding kind of soils in the Channel Islands are believed to be sufficiently stocked with potash. We read that (probably) "the granitic subsoil would in disintegration furnish it in abundance."* The seaweed, much used there as manure, is of value on account of its earthy phosphates (in which the soils would be deficient), and nitrogenous components, rather than on account of its alkalis. The sufficiency of potash in the Rhone Valley clays has already been noticed.

French Granitic Soils.

It is remarkable that the granite areas in Brittany, like those of Galway and Donegal, are peat-covered—a circumstance attributable, doubtless, to proximity to the ocean and consequent dampness of atmosphere and soils. In the regions of Limousin and Morvan the corresponding areas are covered with vegetation, though not of first quality. Analyses by M. A. Leplay† of arable soil, subsoil, and granite rubble beneath, at a depth of 2ft. 7in., set forth the average mineral resources at the disposition of agriculturists in Limousin (Department of Haute-Vienne). These may also be taken as suggestive of the nature and proportion of plant-food naturally residing in the granite-soils of Ireland.

---

* "Watt's Dictionary of Chemistry." Vol. V. "New Edition," p. 211.

† Recorded in *Géologie Agricole*, Vol. I., pp. 65, 66.

Nature of Mineral Substances, &c.	Arable Soil.	Subsoil.	Rubble (at 31 inch. in depth.)
Silica, ...	540	660	767
Alumina and Ferric Oxide, ...	192	230	95
Lime as Silicate, ...	5	3	—
„ Carbonate, ...	—	—	—
Magnesia, ...	20	18	32
Alkalis, ...	14	21	25
Water and Organic matter, ...	210	55	25
Loss and matters not estimated,	19	13	56
Totals, ...	1,000	1,000	1,000

The deficiency of lime and phosphoric acid is the great defect in all granite-derived soils, and the poverty in those fertilizing substances exhibited in these analyses is very striking. Treatment with lime is therefore, the first demand, particularly when it is desired to grow wheat or clover (Risler vol. I., p. 67). The rotation adopted in that region is as follows :—

1st—Potatoes, carrots, or mangle or beetroot, with manure.
2nd—Buckwheat, rye, oats, or other corn.
3rd—Half in vetches with oats, manured ; half in clover
4th—Wheat.

Irrigation.

The waters flowing off granite tracts are, as may be judged, almost worthless for irrigation. Some, however, contain estimable quantities of potash and lime, and traces of phosphates. Reference to the analyses* of the new Belfast supply-water, which flows over granite, will show how small a quantity of lime it contains. M. Truchot records as much as 25 milligrammes of lime per litre (1·75 grains per gallon) from the spring of Sainte Vierge, Sauviat ; and 8·2 milligrammes of potash (0·57 grains per gallon) from a spring in Estandeuil, both in the granite region of Auvergne. These, however, are quite exceptional instances, a quarter of the amount in the case of potash would be a favourable average : and as regards lime, it varies exceedingly, and is not often present in drainage waters flowing off granite.

Felsitic Rocks.

One of the most interesting chapters in Geology is that which treats of felsites. Consisting of, or in composition resembling, volcanic matter extruded from vents in the crust, at various epochs of the earth's history, and being in many cases the plutonic representatives of volcanoes, they form a connecting link, or series of links, between the present and the past. It would be out of place here to dwell upon this aspect of an interesting subject; and even in respect of the area affected, in an agricultural way, by the existence of felsites throughout Ireland, they have not a large claim upon the attention of the reader: the aggregate area of these rocks is comparatively small.

---

*See p. 177.

It may be most convenient to refer to the chief masses according to the order in which the rocks containing them have been described in the previous chapters, commencing with the metamorphic rocks. Numerous dykes of felsite occur throughout the oldest strata in Donegal, Mayo, and Galway; and, though doubtless many of these are of comparatively recent intrusion, some of the larger lenticular masses seem to be of very ancient date.

The chief of these are wide lenticular tracts in central Donegal, near Glenties and Ardara, which, like the other rocks of the district, strike south-westward. Some similarly placed small areas occur to the east and south-east of Donegal (town).

To the west of Lough Mask and near Lough Nafooey, several bands of felsite occur, possessing a south-westerly trend; and they include volcanic ash and agglomerate, which proves that the felsite there is of contemporaneous origin with the Silurian strata. A similar set of volcanic products form the high ground which lies between Charlestown and Ballaghaderreen in Mayo. In the south-east of Ireland a series of lenticular bosses protrude above the drift-covered rocks adjoining; these bosses are the visible portions of bands of potash felsites, associated soda-lime felsites, and andesites which traverse the south-eastern corner of Ireland, from Waterford north-eastward by Enniscorthy; similar bands run in a corresponding direction near Wicklow. Felsitic rocks occur likewise at Portrane, Lambay Island, Chair of Kildare, Craigbarron, Slane, and Bellewstown Hill. The width of the largest of these bands may be reckoned in yards, and none of them seem sufficiently large materially to affect the conditions of agriculture in their immediate neighbourhood. Many of the felsite masses contain large proportions of soda and lime, as well as potash. The decomposition of these masses, therefore, is accompanied by the formation of carbonate of lime, the value of which in soils is well known; by the formation of sodic carbonate also, which on the contrary is pernicious in its effects upon soil's physical condition.

The Old Red Sandstone of Kerry, of the Curlew Hills in Roscommon, and of the Fintona tract in Tyrone, contains protrusions of felsite, in some cases associated with volcanic products.

The knolls which diversify the Golden Vale in Limerick, consist of felsite and other igneous rocks, which are interbedded in the Carboniferous limestone strata, and are therefore believed to be of contemporaneous origin.

Tertiary Acid Rocks.

A long period supervened, during which volcanic, and probably plutonic, forces were in abeyance in the Irish area. They manifested themselves afresh during the Tertiary Age in great eruptions in the north-east of Ireland, and probably in other parts of the country to a less extent. The eruptions were accompanied by irruptions, in the form of dykes and great masses of the class of rocks we are dealing with. Thus there occur pitchstones, trachytes, and rhyolites in Antrim; granophyres, or quartz-felsites and porphyries in the Carlingford district; and the granites of Slieve Donard, in the Mourne group. At Tardree, the trachyte,* a gray and flesh-coloured rock, occupies an area of about twelve square miles.

A Table of Analyses is added, by which the reader will perceive the prevailing deficiency of lime in rocks of this class, and the variation in the proportions of the alkalis. No characteristic, however, is more striking than the lack of phosphoric acid. The first five are given on the authority of the late Dr. Haughton, who did not record if he estimated the proportions of phosphoric acid. The last two exhibit the change which granite undergoes in disintegrating.

TABLE OF ANALYSES—ACID ROCKS.

Components.	Felsite.	Felsite.	Felsite.	Granite.†	Granite.	Granite (André.)	
	Bell Rock, Ovoca, Co. Wicklow.	Carrickburn, Co. Wexford.	Bunmahon, Co. Waterford.	Main granite range, Co. Wicklow.	Mourne Mountains, Co. Down.	Un-altered.	Disinte-grated.
Silica.	81·36	78·40	77·20	72·084	75·00	73·13	74·57
Alumina, ...	7·86	11·32	6·54	14·459	13·24	10·50	12·02
Lime, ...	0·99	0·45	1·81	1·762	0·69	—	—
Magnesia, ...	0·45	0·48	0·60	0·105	—	1·12	0·80
Potash, ...	3·09	4·83	3·69	4·803	4·33	9·04	4·92
Soda, ...	2·63	3·09	3·03	3·014	3·07	1·80	0·46
Ferric Oxide, ...	3·32	0·92	5·82	2·399	2·52	3·16	3·20
Ferrous „ ...	—	—	—	—	—	—	—
Water, ...	—	—	—	—	—	0·45	3·20
Loss, ...	—	0·56	1·12	0·906	0·80	0·80	0·83
Totals, ...	99·70	100·05	99·81	99·532	99·65	100·00	100·00

---

* Rhyolite, as described by Prof. Cole, F.G.S., M.R.I.A., Scientific Trans., Roy. Dub. Soc., Vol. vi., Sec. II., p. 77.

† Average of nine analyses.

The reader will notice that disintegration, in the case of the last specimen of granite, proceeds through the lessening in proportionate quantity of the more easily dissolved substances—potash, soda, and magnesia.

BASIC GROUP.

To the general observer and the agriculturist, as well as to the geologist, this group of rocks presents many elements of interest. They furnish evidence, which is obvious to all, of volcanic action in our island—and this at an epoch which, in a geological sense, is comparatively recent. The remarkable geological feature known as the Giants' Causeway owes its origin to, and finds its explanation in, the form frequently assumed by molten basalt in solidification and subsequent cooling. The rocks which constitute the group extend over almost the entire County of Antrim and a large part of Londonderry, occupying an area of about 1,200 square miles. They form a somewhat elevated plateau bounded by escarpments, which range from 1,000 to 1,300 feet in height. Representatives of the group occur, in many other places; and, as in the case of the acid rocks, they belong to several epochs of the earth's history.

Thus, in the metamorphic tracts, wide outcrops of dark green rock, variously known as hornblende-rock, epidiorites, and hornblende schists, are to be met with, as already mentioned. The chief areas occur skirting the quartzite range of Muckish and Errigal on the north in Donegal, and to the north-east and south-west of Lough Swilly; at Kylemore and at Roundstone in Galway; and a narrow band, to a large extent converted into Serpentine, on the north flank of Croagh Patrick, in Mayo; with several smaller areas to the north-west of Castlebar, in the same county.

Basalts of Carboniferous Age.

The Carboniferous strata contain numerous protrusions of basalts and dolerite, chiefly in the form of dykes of great length and up to 100 yards in width. These, however, are probably of much more recent origin than the rocks penetrated; and notwithstanding the great extent of country covered by strata of the Carboniferous system, little unquestionable evidence is therein afforded for contemporaneous volcanic phenomena. Such evidence seems to be confined to two limited tracts, as pointed out by Sir A. Geikie;* who mentions, however, in this connection, breccias of igneous origin in the Carboniferous strata of south-west Cork.

One of the tracts referred to lies a few miles to the north of Philipstown, in King's County, where basic rocks, accompanied by breccias and pumice, form an isolated eminence, Croaghan Hill, standing 450 feet above the surrounding limestone plain. The other tract lies to the south-eastward of the City of Limerick, where the gently undulating surface of the Golden Vale is broken by terraced ridges, bosses, and knolls. The igneous rocks of this interesting region consist of lavas (?), intrusive sills*, and volcanic agglomerates, disposed in two great sheets amongst limestone strata, and cropping out in rudely circular bands.

---

* "Ancient Volcanoes of Great Britain." Vol. II., pp. 37, *et seq.*

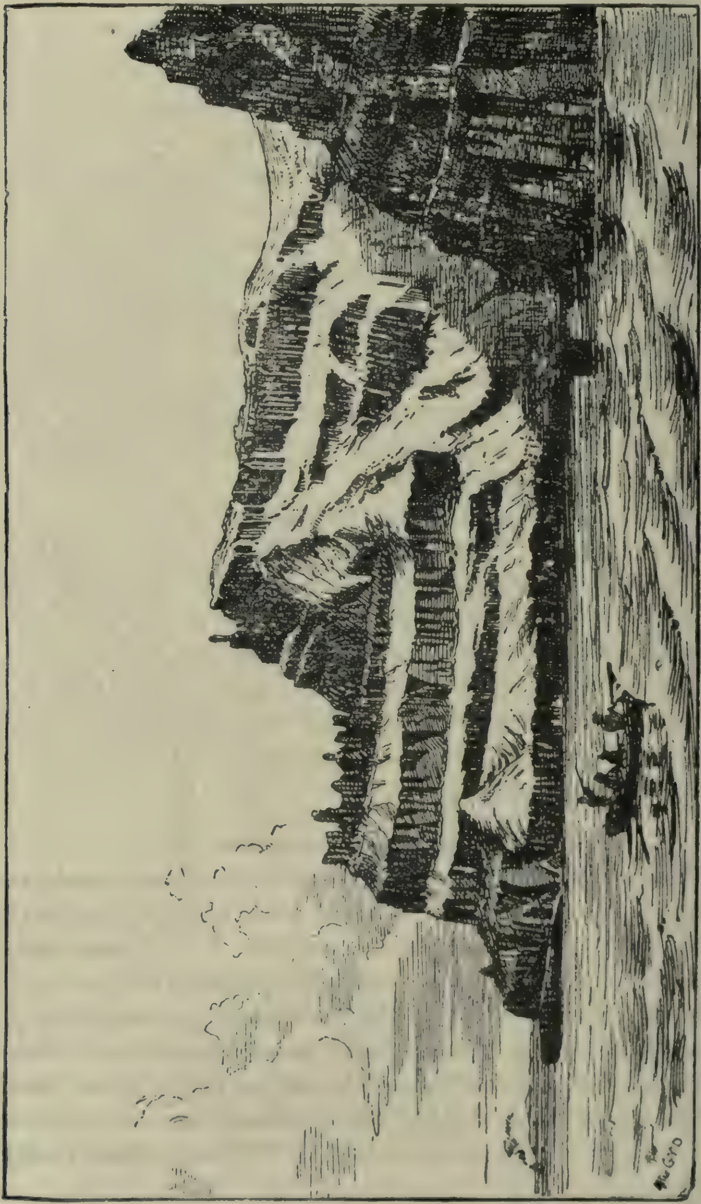


Fig. 35. A view of the Coast Cliffs, forming part of the Amphitheatre, near the Giants' Causeway, showing successive Sheets of Columnar Basalt separated by Bands of Ochreous Clay (Bole) and Volcanic Ash.

---

[*] As recently observed by the writer (see new Memoir of Limerick district).

Basalt of the Antrim Plateau.

In the north-east of Ireland, the basalt of Antrim and Londonderry occurs in massive sheets, which rest upon an eroded surface of chalk (white limestone), and in certain places upon other formations. The north coast presents an array of imposing headlands from Benevenagh in Londonderry eastward to Fair Head in Antrim, few of which are more impressive than that presented in the accompanying view (Fig. 35)* Here is to be seen a succession of basalt "sheets," piled up layer over layer, as they arranged themselves when poured out as lavas from long extinct volcanoes.

The sea-cliffs are represented inland by equally imposing escarpments crowned frequently with mural precipices of basalt: they run southward by Limavady on the west, and by Larne on the east, pursuing sinuous courses in and out of deeply cleft glens. The position of the basalt in relation to the chalk is represented in the following section (Fig. 36)†, the three portions, when joined, showing one continuous line. The gaps in the section are due to erosion, the basaltic sheets having originally been continuous across the whole ground traversed by the section line. The basalt, indeed, extended far beyond its present limits—westward from the escarpment which now towers above the Dungiven and Limavady valley, southward, probably over the northern parts of Down, and north-eastward, to connect with the corresponding rocks of Iona, Staffa, and other islands lying off the Scottish coast. Though having suffered much denudation, by which its surface was lowered as well as curtailed in extent, the basalt still shows a great thickness, testifying to the vast quantities of lava that must have been poured forth from probably many craters active at the time. Denuded cores or volcanic necks are still recognizable in the hills of Slieve Gullion and Slieve Foye near Carlingford.

Ancient Volcanic Vents.

From these vents, and others believed to have existed in Antrim, at Slemish Hill to the east of Ballymena, Bendoo, near Ballintoy, and Scawt Hill near Glenarm, were poured forth lava deluges which, coalescing and overlapping, conjointly formed the Lower Basalt.

After this set of outpourings, a period of comparative quiescence ensued, during which the iron-ore, aluminous, and lignite beds previously mentioned, were formed, probably in lakes and morasses upon the more or less eroded surface of the Lower Basalt. A second set of outpourings followed, forming other layers known as the Upper Basalt of Antrim, portions of which have survived denuda-

---

*Reduced from plate in Memoir of Sheets 7 and 8. Present plate supplied by the Secretary of the Geologists' Association.

† From Explanation of Sheet 14.—Frontispiece.

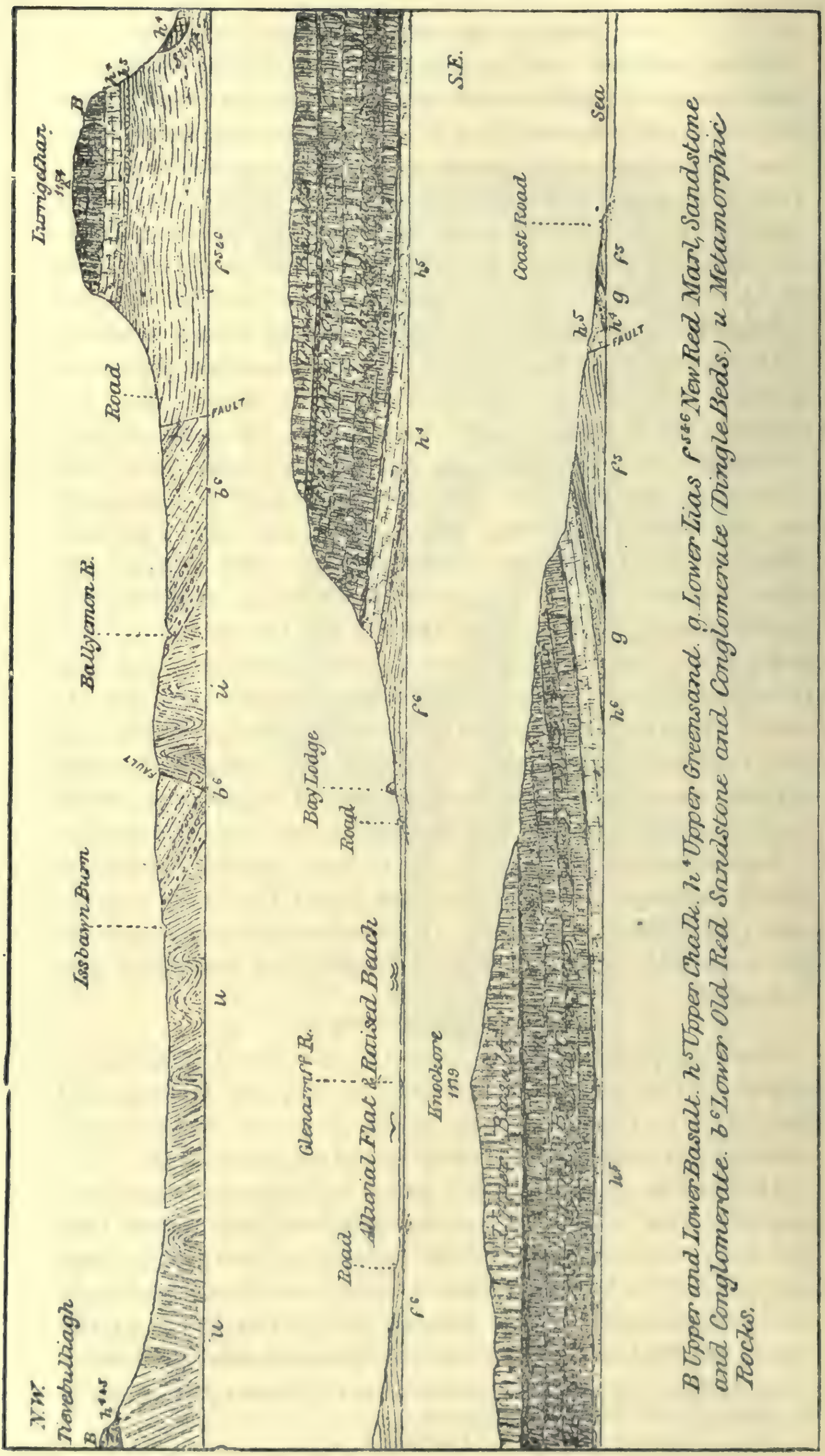

N.W.
Tievebulliagh
B
$h^{4\&5}$
u
Issbawn Burn
b^6
FAULT
u
Ballyemon R.
b^6
Road
FAULT
$f^{5\&6}$
Lurigethan
1154
B
h^4
h^5
Road
Alluvial Flat & Raised Beach
Glenarriff R.
f^6
Road
Bay Lodge
f^6
h^4
h^5
S.E.
Knockore
1179
Basalt
h^5
h^6
g
f^5
h^5
h^4
FAULT
g
f^5
Coast Road
Sea
B Upper and Lower Basalt. h^5 Upper Chalk. h^4 Upper Greensand. g. Lower Lias $f^{5\&6}$ New Red Marl, Sandstone and Conglomerate. b^6 Lower Old Red Sandstone and Conglomerate (Dingle Beds.) u Metamorphic Rocks.

Fig. 36. Horizontal Section in a N.W.S.E. direction across the Hills South of Cushendall, Co. Antrim.

(Scale 1 mile to 3 inches.)

tion, and appear between Portrush and Ballycastle, and between Ballymena and the east coast.

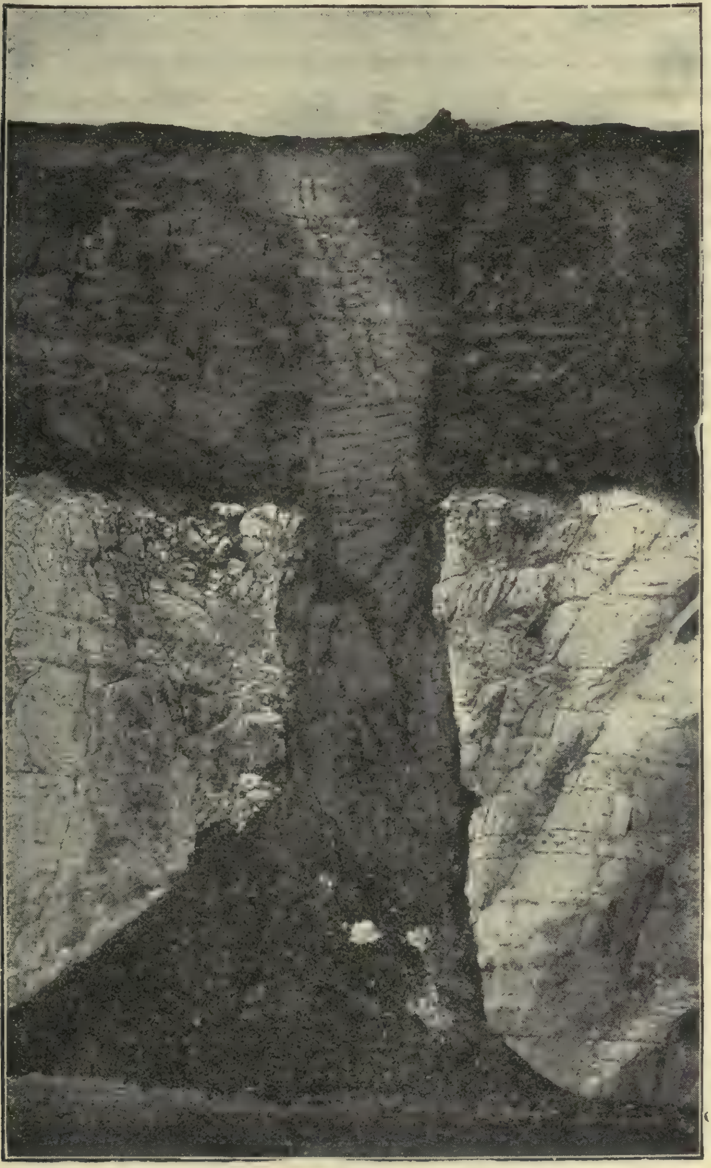


Fig. 37. Dyke penetrating white limestone. and its overlying basalt; at Cave Hill, Belfast.

That some of the lava welled up through fissures which are now filled with solid basalt and are visible as "dykes" is generally recognized, and may be inferred from the illustation here shown (Fig. 37), taken from "Ireland, Industrial and Agricultural," p. 12.

It has been stated that, upon the evidence afforded by the plant remains of the leaf bed, mentioned on p. 109, the period of volcanic activity belongs to the Eocene, possibly Miocene, Age. Elsewhere throughout the country, volcanic necks probably of the same epoch have been met with: one of these, recently described* by Professor Sollas and Mr. M'Henry, occurs near Clifden; and another near Mountcharles,† in Donegal. Numerous dykes are also judged to be of this age by their maintaining a strikingly persistent north-westerly direction. One, nearly 100 yards in width, is traceable almost the whole length of Upper Lough Erne, near its east shore. Frequently the dykes run in pairs, and these occasionally combine; in the Errigal region of Donegal, however, as many as eight pairs traverse a zone some 800 yards in width, and run for some distance side by side without showing any tendency to coalesce. One dyke in this region, previously referred to, has been traced from the summit of the hill, which it crosses, a good way downward, towards the base, and showed no sign of alteration in character through 460 feet of altitude.

Soils after Basalt.

Basalt and related rocks afford a reddish-brown clay on weathering. The clay generally retains particles of disintegrated rock, which to some extent facilitate drainage, while by continuous solution they also supply leading fertilizing substances. Referring to diorites, which resemble basalt in composition, Risler says,‡ thanks to their composition, they form, in decomposing, very fertile soils. Those in Brittany are often employed for the amelioration of soils poor in lime; and applications of sand, resulting from the disintegration of diorites, to the granitic soils of Domfront (Orne), facilitate the cultivation of buckwheat, and render possible that of corn. An analysis of it has been made by M. Durand-Claye, and is here reproduced from M. Risler's work:—

Ferric Oxide and Alumina,	22·45
Lime,	1·78
Magnesia,	1·78
Phosphoric Acid,	·32
Potash (soluble),	·15
Water and substance, not estimated,	16·95
Insoluble residue,	56·57
	100·00

---

* Paper by Professor Sollas, LL.D., F.R.S., &c., and Mr. M'Henry, M.R.I.A.—Transactions of the Royal Irish Academy. Vol. XXX.

† Explanatory Memoir of Sheet 23, p. 48.

‡ *Géologie Agricole*, vol. i., p. 45

It will be seen from this analysis that the most important fertilizing mineral substances are present in strong proportion, especially the important components lime and phosphoric acid.

The following Table of Analyses, prepared from British Petrography,* further illustrate the richness of basic igneous rocks as soil producers, in which respect they stand in strong contrast to acid igneous rocks.

TABLE of ANALYSES—BASIC ROCKS.

No.	Components.		Formulæ.	Basalt.	Amygdaloidal Lava.	Proterobase.	Foliated Hornblende Rock.	Foliated Hornblende Rock.
1	Silica, ...	...	ScO_2	50·56	43·23	50·42	39·20	36·57
2	Alumina, ...	...	Al_2O_3	14·71	21·37	19·10	16·22	15·34
3	Ferric Oxide,	..	Fe_2O_3	3·54	1·69	2·50	4·82	7·57
4	Ferrous „	...	FeO	8·90	9·53	11·03	15·88	14·84
5	Manganese Oxide,	...	MnO	·13	trace,	·40	—	trace.
6	Lime, ...	...	CaO	7·58	6·66	5·81	10·70	12·58
7	Magnesia, ...	...	MgO	4·07	3·57	1·80	6·56	5·98
8	Soda, ...	...	Na_2O	2·94	5·63	5·13	1·45	2·99
9	Potash, ...	...	K_2O	2·10	trace,	1·67	2·69	1·44
10	Carbonic Acid,	...	CO_2	—	2·61	—	—	—
11	Phosphoric Acid,	...	P_2O_5	1·14	·97	·74	·74	·68
12	Ferrous Sulphide,	...	FeS.	2·28	·33	·43	—	-
13	Water, ...	...	OH_2	—	4·49	·98	1·40	1·74
	Totals,	...		97·95†	100·08	100·01	99·66	99·73

† In the case of basalt the analysis also gives 1·71 of TiO_2 (Titanic acid), and ·25 of BaO with traces of lithia and strontia, which bring the full total up to 99·81

Alteration due to Weathering.

In studying the alteration of igneous rocks during the comparatively slow process of disintegration, under the influences of natural agencies, in other words, during *weathering*, perhaps the point most noticeable is the lessening of the proportionate quantities of lime, magnesia, and the alkalis, in weathered specimens, as compared with unweathered or "fresh." The dissolved substances in the forms of carbonates, nitrates, humates, sulphates, &c., usually disappear in the drainage water, or go to enrich any soils which may be in contact with the decaying rock, or fragments of rock. The alteration is well exemplified in four analyses published in Prestwich's work on Geology (Vol. I., p. 53), and reproduced in the following table:—

---

* By J. J. Harris Teall, M.A., D.Sc., F.R.S., (now) Director H.M, Geological Survey.

—	Granite.		Basalt.	
	Unaltered.	Altered.	Unaltered.	Altered.
Silica, ...	73·13	74·57	44·4	42·5
Alumina, ...	10·50	12·02	12·2	17·9
Lime, ...	—	—	11·3	2·5
Magnesia, ...	1·12	0·80	9·1	3·3
Potash, ...	9·04	4·92	0·8	0·2
Soda, ...	1·80	0·46	2·7	
Iron Protoxide, ...	—	—	12·1	—
„ Peroxide, ...	3·16	3·20	3·5	11·5
Titanic Acid, ...	—	—	—	1·2
Water, ...	0·45	3·20	4·4	20·4
Lossac, ...	0·80	0·83	—	—
Totals, ...	100·00	100·00	100·5	99·5

Irrigation.

Drainage waters flowing off basalt, or issuing from springs in a basaltic region, are well worth utilizing, inasmuch as they all contain proportions of lime, and probably phosphates. That they are rich in lime, as compared with the waters flowing off granites may be seen by comparing the analyses of waters drawn from the north of Belfast—off basalt, with those of waters drawn, say, from the Mourne granite region. The following details may also here be reproduced. They are taken from analyses also made by Professor Dewar for the Belfast Waterworks Committee.

NUMBER of Grains per Gallon of Carbonate of Lime, producing Temporary Hardness; and of other Lime Salts, producing Permanent Hardness.

—	Stonyford Stream, Y. Bridge, 14th Apl., 1892	Lough Neagh, Sandy Bay, 14th Apl., 1892.	Lough Neagh, below Toome, 19th Apl., 1892.	River Main, below Ballymena. 16th Apl., 1892.
Temporary Hardness, ...	5·39	1·61	4·40	6·97
Permanent Hardness, ..	3·40	2·91	2·91	1·82
Total, ...	8·79	7·52	7·31	8·79

Economic Minerals.

Tin ore abounds in the granite and "elvans" of Cornwall; and the rich diamantiferous soils of Kimberley are believed to be formed of igneous rock *débris.** It is strange that the corresponding rocks in Ireland should be almost devoid of minerals of economic importance. The chief Irish minerals are therefore enumerated under the Sedimentary Groups.

* "Ingwadi Yami," by J. W. Mathews, M.D., p. 151—Dr. Mathews gives his opinion in accordance with observations of Mr. George J. Lee and others. Prof. Bonney, F.R.S., says (*Geo. Mag.*, 1895, p. 501), that he considers the diamantiferous rock—the so-called *Kimberlite*—to be a breccia, consisting mostly of basic materials, ejected from deep-seated portions of the crust, now filling (having fallen back into) pipes which were formed during volcanic explosions.

Slemish Mountain from Ballymena.*

* From Explanation of Sheet 20, page 18.

An acquaintance with the geological facts treated of in the previous chapters, will enable the reader to appreciate the evidence to be presented in this, for the former existence of glacial conditions in this country, and contingent phenomena. What has already been set forth in Chapter III. sufficiently indicates the important place which the distribution of glacial Drifts holds in determining the agricultural conditions of a large part of Ireland. In the present chapter a brief statement of the general history of the glacial deposits will be given, especially as regards development in Ireland; but as these deposits cover by far the largest part of the country, and contribute more materially than all the other geological Formations to the production of the soils, a special section (No. III.) will be given, in which their varied distribution, and diversity in the different provinces, will be stated in fuller detail.

Distribution of Erratics.

Amongst the striking facts indicative of glacial conditions, is the occurrence of massive blocks of stone in great numbers and various positions, on hill tops, mountain flanks, and in valleys throughout

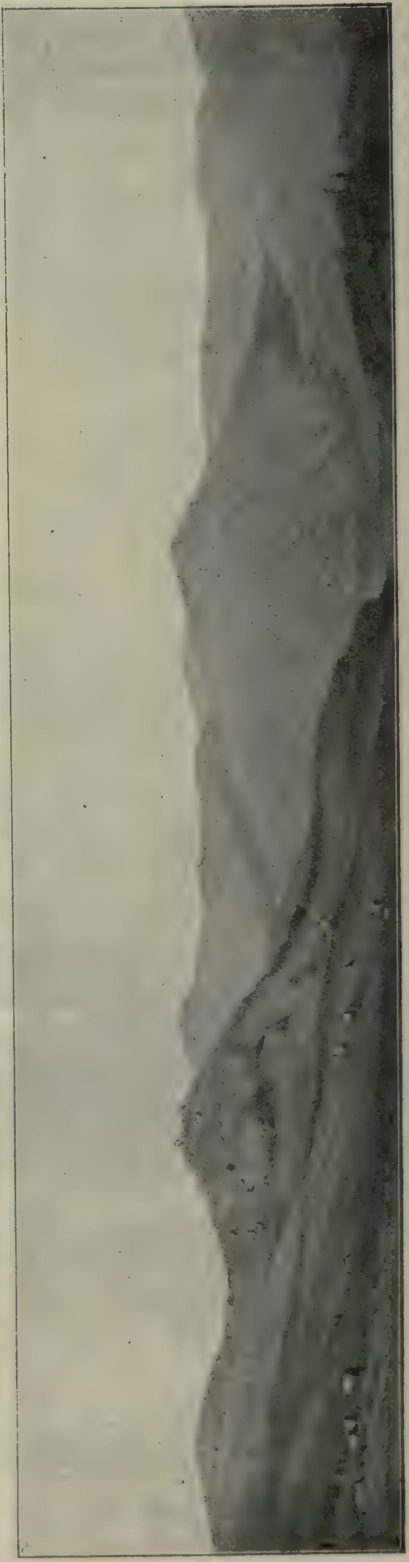


Fig. 38. View showing the position of granite erratic blocks upon a hill of Silurian slate and grit, near Luggala, in Wicklow. The erratics were transported from their origin in the granite hills seen in the distance, across the valley of the Annamoe River to Sleamaine Hill in the foreground where they now rest. From drawing by G. V. du Noyer, once of the Geological Survey of Ireland

the country.* They frequently rest upon portions of the crust from which they could not have been derived, and are therefore termed *erratics.* Close examination of their material enables the observer to identify the localities from which they have come. The level at which each erratic now reposes, as compared with that of the ground crossed in transit, may thus be judged, and the circumstance will often be found to be such as to preclude the supposition that running water could be the means of transport. The erratics seen in the accompanying view of some of the Wicklow hills (Fig. 38), having come from the granite range in the distant background must have been borne across the deep valley which intervenes between them and the hills which form the foreground of the picture.

Some erratics are of very large size, as may be seen in the following woodcuts (Figures 39 and 40).† In the first instance, a mass of Old Red conglomerate rests upon felsite, and even the portion of it not concealed is of considerable dimensions.

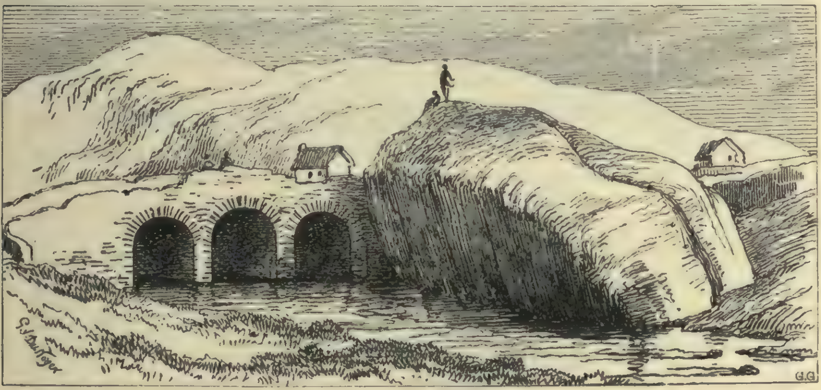


Fig. 39. Cloughlowrish Stone.

Erratic Boulder of Old Red Conglomerate at Cloughlowrish Bridge.
Sheet $\frac{24}{3}$, County Waterford.

In the second instance, next page, an erratic measuring 20 feet by 12 feet by 8 feet, to be seen near Ballyhaft Cottage,‡ one mile to the south of Newtownards, Co. Down, is wholly visible, and poised almost upon an edge.

Another such block, measuring 20 feet by 15 feet by 15 feet, to be seen south of Ballyhalbert, on the east side of Carlingford Lough, rests in such a manner as to admit of being easily moved.§

---

* See reference to Sir R. Griffith's report thereon, p. 133.

† From Explanation of Sheets 167, 179 ; p. 16.

‡ From Explanation of Sheet 37, p. 41.

§ Explanation of Sheets 37, 38, 39 ; p. 41.

Erratics may rest upon Drift in the low ground, or be situated upon hill tops forming conspicuous objects in the landscape, as shown in Figs. 41* and 42.†

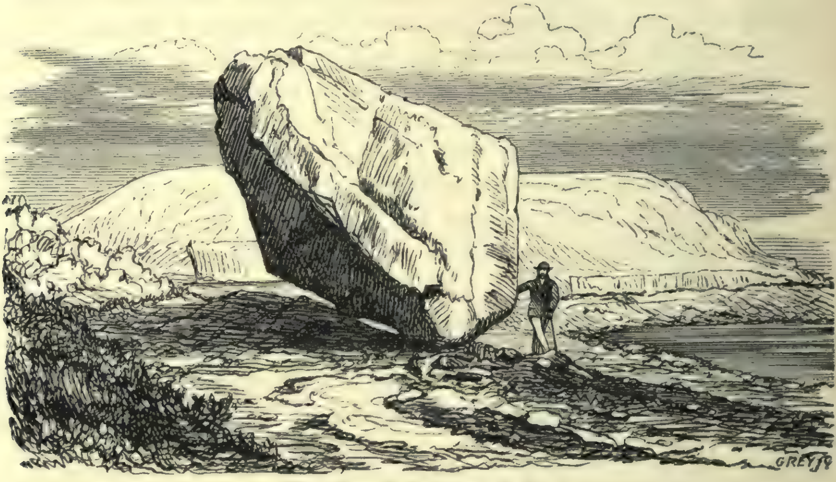


Fig. 40. Butterlump Rock.
Boulder of Basalt on Floor of New Red Sandstone, near Newtownards, Co. Down.
(From a Sketch by the late J. V. Du Noyer.)

It is many years since the distribution of erratics claimed the attention of scientific observers in this country; and an account of

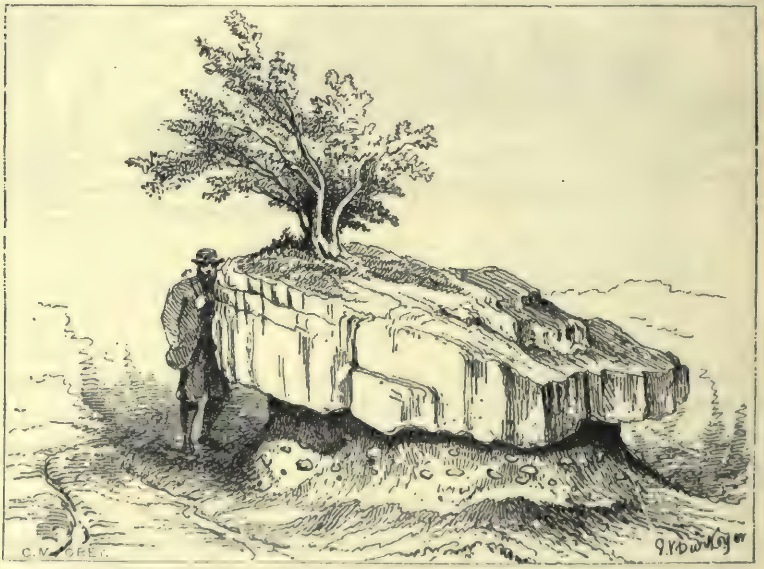


Fig. 41. Block of gray limestone, about eight feet long by three deep, and five broad, resting on a patch of boulder drift on S. side of road, three miles east of Clonmacnoise. Ord. Sheet $\frac{8}{3}$, King's County.

---

* From Explanation of Sheets 98, 109; p. 21.

† From Explanation of Sheet 193; p. 19.

them as they occur in certain parts of Ireland was drawn up by Sir R. Griffith. This account appears in the Thirteenth Report of the British Association,* in which the author records the occurrence of granite boulders resting on, rarely included in, the gravels below. He also notices the distribution of rocks from the Curlew hills over the ground in the limestone valley of Ballymote and Tubercurry; granite from the Ox Mountains along the whole line of coast from Easky to Erris, in Mayo; and refers to the occurrence of granite boulders, probably from Galway, in the valley of Roscrea. The officers of the Geological Survey have noted the occurrence of the same granite as far south as the vicinity of Limerick; and the northern part of Co. Cork.

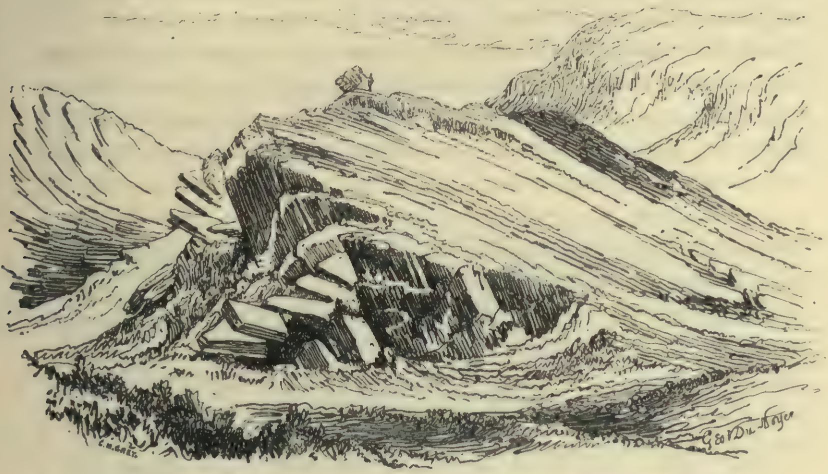


Fig. 42. Perched boulder, S. flank of Mount Gunnery, Townland of Coom, 2 miles north of Dunmanway, Co. Cork.

Agency of Distribution.

The only natural agencies known which could have accomplished the transport of erratics, and placed them where, and as, they are now found, are either ice-bergs floating over the country during a period of submergence, or a thick mantle of land ice which moved across portions of the country in various directions. The former means has been suggested and contended for by some authorities, and as the country has frequently been covered by ocean waters, its submergence in glacial times has been at least possible; and the occurrence of shell-bearing gravels at some 1,300 feet above the sea on the flanks of the Dublin mountains has been appealed to as corroborative evidence for subsidence of the land to this extent at least. Difficulties of detail, however, which will be mentioned later on, stand in the way of an unquestioned acceptance of this hypothesis; and it may suffice to mention here, that equally large erratics are to be met with, correspondingly placed on hill sides and valleys of Switzerland, where recent submergence is not contended for.* Their transport and deposition are due to an immense extension of the *mers de glace* and glaciers which now linger only on the higher regions of the Alps. Those *mers de glace*, or ice-sheets, which filled the valleys and covered up the low-lying hills, spread outward, and, as great glaciers, ground, polished, and scored the crust over which they moved, by means of the sand, gravel, and stones stuck fast in their soles. They wrenched off projecting pieces of rock, detached masses from the mountain sides, and received *débris* which descended upon them from above; and these cargoes of earth and stones the glaciers bore along, to drop them where the ice wasted itself on the outskirts of the glacial region; or to distribute them along their courses when melting, as they ultimately receded to their present limits.

---

* 1843. Part II., pp. 40–42.

The significance of the facts and conclusions here cursorily reviewed, as aiding in the elucidation of surface geology in the British Isles, has long been recognised. The facts which establish the correspondence in conditions between Ireland and other obviously glaciated regions may be classified as follows:—

(1.) The occurrence of erratics.
(2.) The striation of smoothed and polished rock surfaces, to be observed in many places throughout this country.
(3.) *Roches moutonnées*—rounded and smoothed hummocks of rock, prominent in several districts.
(4.) The thick deposits of boulder-clay containing blocks of stone, which are often smoothed, polished, and striated.
(5.) Hillocks and narrow ridges of stratified sand and gravel—eskers.
(6.) Moraines.

Glacial Striæ.—The surfaces of rock in many places may be seen to be smoothed and striated, and even grooved, as if by some great planing machine. The agent was none other than an ice-sheet, holding—as in the case of glaciers—stones, gravel, and sand, set in the lower surface, its *sole*. The parallelism to be noticed amongst the linear markings throughout a locality, and even over wide areas, is confirmatory of the conclusion that they are due to attrition by a

* Dr. J Geikie, writing with reference to the great ice-sheet which covered northern Europe during the Glacial Period, says:—"Partly by means of rock striæ and *roches moutonnées*, &c., but chiefly by the direction of the transport of Erratics, geologists have been able to track the general course followed by the Ice-sheet," which "radiated outward from Scandinavia, moving across the great plains of Europe into Belgium," and Middle Germany.—"Great Ice Age," 3rd. Ed., p. 437.

great, continuous, moving mass; and even when the striæ diverge, or perhaps indicate movements in opposite directions in different localities, all are due to the existence and movement of a great sheet of ice which covered the island, and, probably, at one period of the ice-age, coalesced with one which for the most part covered Scotland, and extended north-eastward over Scandinavia. Evidence for this extensive ice-covering is to be found as far south as the Bristol Channel and the valley of the Thames. In the Irish area, it is inferred, from equally conclusive evidence, that the ice-sheet extended as far as, and probably southward of, Cape Clear, and westward into the Atlantic for a considerable distance, to waste itself in the ocean by throwing off bergs, as do the *mers de glace* of the Arctic and Antarctic regions of the present day. (Compare Fig. 43.)

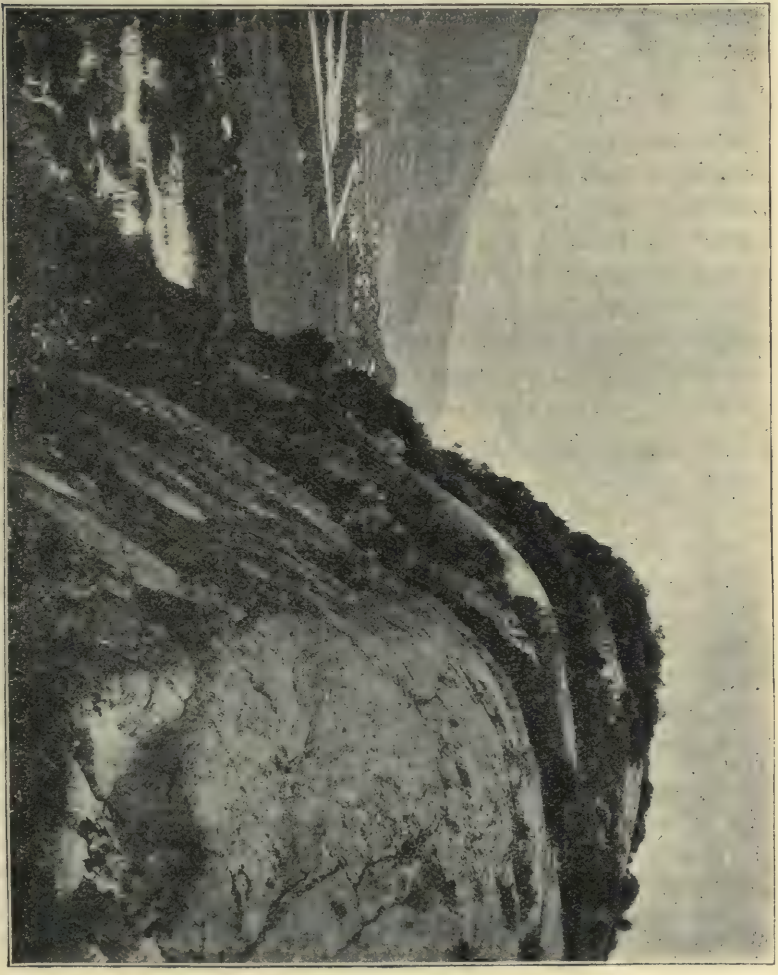


Fig. 43. Taken from "Ireland, Industrial and Agricultural," p. 13, showing rock rounded by glaciation, at Loo Bridge, Co. Kerry.

General Glaciation.

The interesting subject of the rock-striation throughout Ireland was first systematically studied by the Rev. M. Close; and Professor Hull,* basing his judgment upon the data published by that author, and subsequently collected by the officers of the Geological Survey, came to the conclusion that a zone of maximum snow and ice accumulation, at one period of the ice-age at least, extended from North Galway to South Antrim—the country on either side of the zone being also covered with a frozen mantle, except perhaps the summits of the various mountain groups. A spontaneous though sluggish flow of the mass, was necessitated by its constantly increasing height and weight—northward, and southward, from the zone, where, as pointed out by Mr. Close, the ground is but slightly if at all glaciated†: and the flow would have continued as long as the accumulation maintained its magnitude by constant accessions of frozen moisture wafted from the Atlantic. Throughout this period, and, indeed, in later glacial times, more or less independent snowfields existed in the great mountain groups which had their own systems of glaciers. Traces of the striæ graven by the ice, together with other glacial indications, may be traced to great elevations. In addition to the evidence of local glaciation, striation and boulder clays, attributable to the great ice system, are to be found at heights of 1,500 and 1,600 feet, and possibly higher, which show that the ice-sheet must have been of considerable thickness at these points, and may here and there have exceeded in depth 2,000 feet at the present coast-line.

Throughout Ulster, striæ in many places take a direction transverse to that taken by those of the system of glaciation described by Prof. Hull.* It is known that ice, though apparently so brittle and unyielding, is capable, under pressure, of accommodating itself to narrow and winding channels, and of spreading itself outward when its margins are free, like so much wax.‡ Instances have been observed in Europe and in America where different parts of the same mass of ice must have flowed in different directions, according to the configuration of the ground. In Ulster, however, the westerly direction of the striæ is as undeviating as the northerly, and is to be found at heights of 1,200 feet at Glenarm, in Antrim, 1,250 in Slieve Beagh in Tyrone, and 1,200 in Slieve League in Donegal, as well as at 1,100 feet in the Nephin Group in Mayo, and 2,184 and 2,012 on Ben Gowar and Sharmaunafeolagh, respectively, in Galway. Judging from the positions, number, and directions of these striæ in Ulster and North Connaught the writer inferred that at a certain period of the ice-age, probably antecedent to that of the ice system described by Professor Hull, a stream of great magnitude flowed across Ireland from a British centre of accumulation (Scotland, in the case of Ulster)* where the ice-sheet was 3,000 to 3,500 feet in thickness. It is here briefly referred to as a likely means of accounting for the existence of boulder-clays, as at Westport (see p. 105), beneath those deposited by the system centering in the Galway-Antrim snowfield. The reference also serves to illustrate the nature and variety of questions presented by glacial geology, as well as to emphasize the changes in directions of movement, and conditions which prevailed, throughout the period of the earth's history with which we are dealing; and the numerous varieties of rock contained in the Drift.

---

* See "Physical Geology of Ireland," 1st Ed. by Professor Hull, M.A., F.R.S., for the lucid treatment of the glaciation of the country referred to here.

† Striæ have been observed in a few places along this zone, their trend being mostly westward.

‡ The resemblance holds only in general effect; in physical process it fails.

To the conditions indicated in the phenomena mentioned above, must be added recessions and renewed extensions of ice-sheets throughout the period. Dr. James Geikie† gives the series of changes which occurred in Scotland as they are inferred from the deposits known to be of, or closely associated with those of, glacial origin—namely, Lower Boulder-clays, Interglacial beds, Upper Boulder clays, and Moraines. These deposits all have representatives in Ireland, and will now be described.

Boulder Clays.—The main interest to the agriculturist centres in these relics of the great glacial episodes. In a previous chapter (VIII., p. 93), mention was made of the quantity of detritus and disintegrated rock which must have existed in Ireland prior to the glacial epoch. The vastness of the quantity may be understood when it is considered that what now remains, though in places 100 feet in thickness, is probably much less than that which was transferred to the ocean by the moving ice-sheet, subsequently by waters of the melting ice, and since by denuding agencies. In many places, especially on the higher grounds, the soils have been formed obviously from the rock beneath—*in situ*. It therefore becomes a matter of discernment to be able to say where true Drift exists, and where it passes into soil directly derived, as above. True Drift is easily recognised—(1) when it rests upon a glaciated surface, or (2) upon a lower boulder-clay; or (3) when rock detritus is intermingled, which is foreign to the locality; or (4) when the clay contains glaciated boulders.

---

* See Paper, on "The Directions of Ice-flow in Ulster," by J. R. Kilroe. Quar. Jour., Geological Society; November, 1888. Prof. Hull mentions this system in the second edition of his Physical Geology. See footnotes on pp. 141, 202.

† "Great Ice Age," 3rd Ed., pp. 421-2.

The glacial deposits are represented on the Geological Survey published one-inch maps by strippled dots over the colour appropriated to the Formation or rock beneath. From these maps that which accompanies this book has been prepared, colours appropriated to the rocks being used only where considerable areas of these rocks are to be seen at the surface—that is, where the ground is quite or almost bare of Drifts. The Drifts may form flat undulating country, or may be disposed in oblong hillocks, *drumlins*, which maintain, locally, remarkable parallelism of trend. The boulder clays, distinguishable as Lower and Upper, may be seen in many sections without the intervention of other deposits. Often, however, stratified sands and gravels underlie the Upper Boulder-clay, and the same stratified deposits overlie denuded Lower Boulder-clay, only two members being visible in each section. These circumstances are presented in the following view (Fig. 44*) and sections (Figs. 45† and 46‡, the first from a description

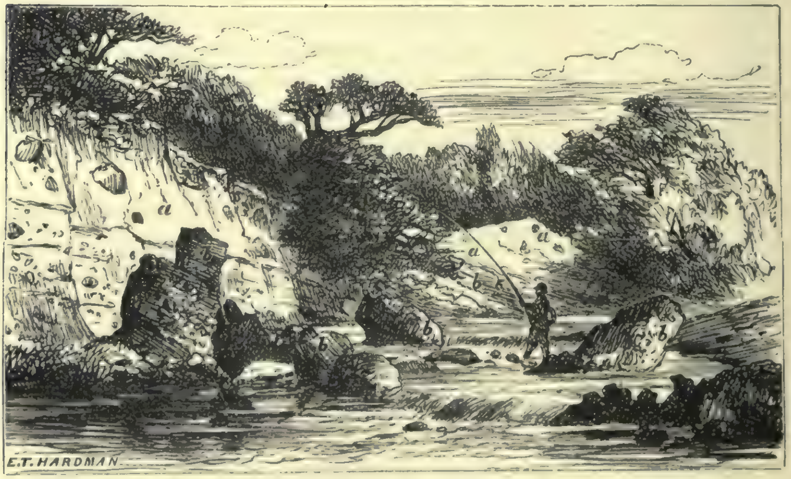


Fig. 44. On the Dinin River, S. of Jenkinstown Demesne, Co. Kilkenny.
a. Upper Boulder-clay.
b. Calcareous conglomerate (Middle Gravels consolidated by lime carbonate).
b'. Masses of same fallen into stream.

---

* From Explanation of Sheet 127 (new edition), p. 17.

† From Explanation of Sheet 127, p. 18.

‡ From Explanation of Sheet 34, p. 21.

of part of Kilkenny. The disposition of the Upper Boulder-clay with respect to the Lower, and intervening sandy beds, is indicated in section in Fig. 45, and in the next section the Middle Sands and Gravels are shown resting upon eroded Lower Boulder-clay. When sands and gravels do not intervene, the existence of Upper and Lower clays can be recognised with certainty only when they present a strong contrast in character and contents, as in the cases previously mentioned at Westport, and at Bantry.

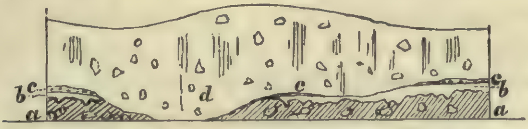


Fig. 45. Coonbeg, Queen's County. Upper Boulder-clay (*d*) resting on denuded surface of Lower Boulder-clay (*a*). *b* and *c* Sands, &c , intervening.

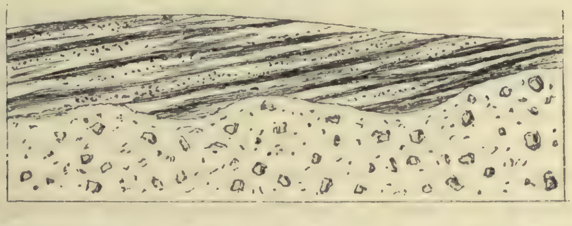


Fig. 46. Drift Section near Eshbane, Co. Tyrone, showing Interglacial Sand and Gravel resting on denuded surface of Boulder Clay.

Lower Boulder Clay or **Till** is usually observed to be a hard, tough, close-textured mixture of sand and angular gravel with more or less *clay*, containing partially rounded, smoothed, and striated blocks. In colour it changes with that of the rock whence it has been derived, dark gray when formed of limestone detritus, red when formed of Old Red and of New Red Sandstone, brown when derived from basalt. In Donegal and Londonderry the lowermost boulder clays consist of mica schist *débris;* and with the exception of the district to the north and west of, and around the town of Donegal, it is rare to find limestone boulder-clay to the north of Omagh in Tyrone. This valuable clay, with limestone boulders, has been transported northward over the metamorphic rocks in Mayo from the country lying to the south of Castlebar, doubtless by the system of ice-movement described by Professor Hull; and by the same system similar valuable materials have been carried southward over the Silurian grits, from the limestone tract near Clones and Monaghan; over the grits and slates of the same Formation and granite, in the counties of Dublin, Wicklow, East Kildare, Wexford, and Waterford, and over the Upper Carboniferous sandstone and shale series in Queen's County and Kilkenny.

Limestone boulder-clays are to be met with in the valleys of the Silurian ground in central Ireland; in one section, for example, near the centre of the Keeper Hill tract, to the south of Nenagh, section of limestone detritus was met with, showing 20 feet in depth, and studded with glaciated limestone boulders, the deposit being covered with 6 to 10 feet of locally-derived materials. Mingled with the limestone *débris* were boulders of Old Red Sandstone, comparatively few in number, and fragments of Galway granite, indicating the direction whence the materials travelled and the distance whence some had come. In the valleys of the Comeragh Mountains the same kind of boulder-clay is noticeable; and in south-west Cork it is also encountered, as already described. There is little doubt that an exceedingly wide distribution of limestone boulder-clays formerly obtained throughout Ireland—perhaps forming a nearly continuous sheet over the lower grounds of the south—until cleared away by local glaciation, and subsequent denudation. That the Bantry limestone clays are not of local origin is rendered certain by the following facts, viz., first, the Carboniferous system of south-west Cork contains but a few insignificant limestone beds. Secondly, no limestone in mass occurs nearer than Kenmare; and there the rock is *cleaved*, while the boulders in the till at Bantry are not so. Thirdly, they are such as would be yielded by the limestone which commonly forms the Central Plain, the nearest point of which is many miles distant.*

The limestone gravel and boulder clays in the several regions mentioned are generally covered by, or intermingled with, locally-derived material of greater or less thickness, as previously mentioned. This is especially noticeable where ridges and knolls protrude through the Drift-covering, though an upper Drift, usually boulder-clay, is also recognizable in regions where ridges and knolls do not appear; and the circumstances of the deposits preclude the supposition that both could be simultaneously collected, carried, and deposited. It appears very difficult to imagine how a sheet of land-ice bearing the materials of an upper layer could over-ride without greatly disturbing and even removing altogether a lower and previously formed deposit. For this reason, and judging from the character of the Upper Boulder-clay, it has been supposed that this was deposited from floating ice-bergs. It is certain, however, that the former hypothesis is necessary, in many instances; and it finds verification in present glacial regions.

Middle Sands and Gravels.—Stratified sand and gravel are to be met with in many places, containing a large admixture of limestone fragments and sand. They admit of free percolation, and are in consequence better adapted to tillage and rotation crops, than to letting out in lea, inasmuch as being deficient in clay, and potash, such soils are incapable of supporting strong grasses. They clothe themselves, however, with a sweet leguminous herbage, where lucerne and sainfoin especially would flourish. Continual pasturing and cultivation of such land, fairly treated as regards farmyard manuring, tend to produce a more or less retentive sod; or an uppermost layer of sandy loam over a gravelly subsoil is formed through the dissolving out of carbonate of lime from the more or less earthy limestone fragments, leaving a residuum of clay. Capillary attraction and plant-roots also draw upward materials which decayed crop residues leave, in a finely divided condition, in the soil.

---

* Similar limestone occurs at Killarney, twenty-two miles distant, but not in such width of outcrop as to afford so large a proportionate admixture of limestone detritus, as is to be seen at Bantry.

The title "Middle Sands," &c., seems to be fairly justified by what is to be observed in a few sections where they are interposed between the Upper and Lower Boulder Clays,* as well as the manner of their occurrence in many places, as described on a previous page (p. 138). A subsidence of the land concurrently with a change of glacial conditions has been invoked to account for the stratification manifest in these deposits. Submergence to the extent of 400 or 500 feet would account for the arrangement referred to, in the case, at least, of the sands and gravels throughout much of the central plain; but other means of explanation are demanded for the stratified arrangement of the limestone gravels at much higher levels than 500 feet: for example, 1,300 feet, as given by Mr. Close and Mr. J. Kelly, and 1,235 feet by members of the Geological Survey. The explanation required is apparently contained in the suggestion of Dr. J. Geikie that the limestone gravels of Dublin, Wicklow, &c., are but a form in which the Lower Boulder Clay has been laid down in those regions, much of the argillaceous matter having been carried away by the rushing waters of the melting ice-sheet. The existence of sea shells is not opposed to this explanation: their occurrence at so high a level in these glacial deposits, and the manner in which their occurrence bears upon glacial phenomena, form interesting geological questions which are somewhat outside our present purpose.†

Upper Boulder-Clay.—This member of the glacial series has a much smaller extension and thickness throughout Ireland than the Lower Boulder-clay. It is usually sandy, contains angular boulders and fragments, and is of a yellowish colour, owing to the perfect oxidation of the small quantities of iron contained therein, towards which the porosity of the clay contributes. Besides being itself partially stratified, it contains layers of sand, which accounts for the remarkable difference often observable between, perhaps, adjoining fields where this Clay forms the soil and subsoil. The layer or layers of sand may appear—*i.e.*, "crop out"—over a certain space and give a porous, shallow, poor soil and subsoil, which swallow up much manure without showing lasting improvement; whereas not far distant, the soil may be argillaceous, deep, and grateful.

---

* See "Physical Geology of Ireland," by Professor Hull, LL.D., F.R.S., 2nd edition, p. 311. "Great Ice Age," by Dr. J. Geikie, F.R.S., &c., 3rd edition, p. 413.

† The ice, containing the shells and enclosing matrices—boulder-clay and gravels—seems to have been pushed upward from the Irish Sea-floor, on to the flanks of the Dublin Mountains (see New Memoir of the Dublin area). Lower Boulder-clay which contains marine shells, and has been carried westward, also occurs in Co. Londonderry. See p. 202.

The very wide extension which has been claimed for the limestone boulder-clays throughout Ireland would lead one to expect an admixture of such materials with that drawn from local sources, as has been the Upper Boulder-clay; and this may be frequently observed in the Silurian tracts. In many Drift sections in these tracts, a limestone boulder or pebble promiscuously set here or there, frequently low down in the section, sometimes near the surface, is the only evidence, though reliable, for the former existence of limestone boulder clay in such localities. The superposition of locally-derived materials upon limestone boulder-clays and gravel, in the tracts referred to, proves that the former must have been transported, to some extent at least. The promiscuous occurrence of limestone boulders therein also shows to what an extent mixing must have taken place; and the further fact that large boulders occasionally, and moderately sized blocks frequently, occur, proves that ice, or a mud-deluge consequent upon the melting of ice, must have been the mixing and transporting agency. Running water would have carried away all the clay and finer sand.

Loss through Solution.

It has previously been observed that the Upper Boulder-clay when present, or the uppermost portion of the Lower Boulder-clay, when only this is discernible, has lost a great quantity of calcareous material. The wetness of the climate and prolonged cultivation of the ground, has had the effect of dissolving out the greatest part of the lime from the portion of the superficial deposits in which the agriculturist is principally concerned. Hence most of the earthy limestone blocks and fragments, which the uppermost clays contained, now exist there in the form of "rottenstone." Pebbles of chert sometimes occur abundantly in Drifts, where one may look in vain for pieces of limestone, though the chert was once enclosed in that rock. It has remained, while the enclosing limestone became dissolved and carried away; its presence, therefore, is sufficient indication of the source whence much of the material containing the chert fragments has come.

Ill-Effect of Drift Distribution.

Instances may be pointed to in which the usually good soil prospects, attaching to a limestone area, are marred by the distribution of Drifts drawn from unpropitious sources. Thus several square miles lying some distance (seven miles)to the east of Westport, are rendered exceptionally sterile by a sandy drift carried northward from the Lower Carboniferous Sandstone ground near Lough Mask. The Drift there is deposited in low ridges, and these are barren; while the hollows between the ridges—where the limestone makes its appearance—are quite fertile. The same northward ice-flow which produced such unfavourable results in the district named, distributed the Upper Boulder-clay over the limestone Drift between Westport and Newport with the ill-effects dwelt upon in Chapter III.

Deposition of Upper Drift.

In the Upper Drift of this region, reposing upon the Lower, occur immense erratics of grit, the source of which can be identified This source lies to the south of the Croagh Patrick, and it can scarcely be doubted that the means of their transport thither was ice—viz., an ice-sheet which moved northward across the range, and produced rock scorings which are to be observed in many places to the south of Croagh Patrick. It is a remarkable fact that an ice-sheet bearing materials from that source should have moved across the region of Westport, on the eastern shore of Clew Bay, without carrying before it the previously-formed thick deposit of limestone boulder-clay. This, however, seems to have taken place, though the contrary must have occurred to the east of Westport, in the region previously described, inasmuch as no boulder deposit now remains there save the sandstone Drift. The difference in condition between this region and that nearer to Westport, might be explained by supposing that the drumlins of limestone boulder-clay were shielded from the ploughing action of the northerly ice-flow by the Croagh Patrick range, while the other locality lies in the open plain, and was thus exposed to its full strength.

The above remarks not only presuppose that an uppermost layer of Drift was formed by an ice-sheet, but that this was of subsequent date to one which laid down a much more important deposit of limestone boulder-clay—a boulder-clay which we have been treating of as Lower, and was probably carried westward from the Central Plain.

Upper Boulder-clay at Bantry.

The boulder clays of Bantry must be regarded in a similar light. For the Upper Clay there is made up of local detritus, as already mentioned, which could have been laid down by an independent glacial system centering in the Reeks—such, indeed, as Professor Hull represents as having existed there contemporaneously with his north-easterly axis of glacial accumulation; while this, an independent system, *could not* have deposited there the great thickness of limestone Drift, the Lower Boulder-clay.

Upper Clay and Moraines.

The Upper Boulder-clay of the Silurian tracts merges with moraine matter, both covering the limestone detritus, when this is met with in the valleys. The Boulder-clay is frequently to be found there covering glacial sands and gravels; but these are not to be confounded with gravels laid down by floods issuing from latest glaciers, which usually coalesce with moraine matter and may overlie Upper Boulder-clay. The deposition of the Upper Clay is closely connected with the distribution of erratics; both are supposed by some authorities to have been laid down by floating ice-bergs as stated above; and the necessity for such a supposition is believed to be strengthened by the semistratified character of the Clay.

With regard to the partial stratification, it may be mentioned that the upper Drift between Westport and Newport shows it very distinctly, though having originated probably in land-ice; the gravels in the Dublin mountains are stratified, and later investigations show that even in their case the hypothesis of submergence is not necessary to account for stratification. If we take a case of similar Drift, mentioned by Professor Hull, that at Kilkelly in Mayo, the most elevated point of the area in which the detritus forming this Drift originated—the great sandstone tract lying between Kilkelly and Charlestown—is scarcely more than 150 feet higher than the plain over which the detritus is distributed. When we attempt to apply the submergence hypothesis here—and the same difficulty in detail presents itself elsewhere—there would not have been depth of water sufficient to float great boulder-laden ice-bergs, leaving any of the sandstone tract unsubmerged; nor height of ground upon which a *mer de glace* could accumulate, while submergence of the ground in question to a great extent obtained.

It has been stated above, with regard to the nature of the Upper Boulder-clay, that it frequently agrees in character with locally-derived detritus; also that in many places locally-derived detritus forms the soils. Throughout large areas in Ireland the Drift present is largely what the local rock at each point would yield. Only in the south-east of Ireland, and other places mentioned, do the Clays in their lowermost parts present an aspect foreign to the locality. Taking these circumstances into consideration, it will be apparent that the soils and subsoils throughout the country, even in the Drift-covered areas, may be largely such as could be judged from an ordinary geological map. Greater admixture of ingredients obtains, on account of the divers shiftings, tossings and washings of detritus; and deposits of unexpected character may be met with here and there, some beneficial, others adverse—for the most part beneficial — to agricultural prospects; but on the whole a very remarkable correspondence exists between the

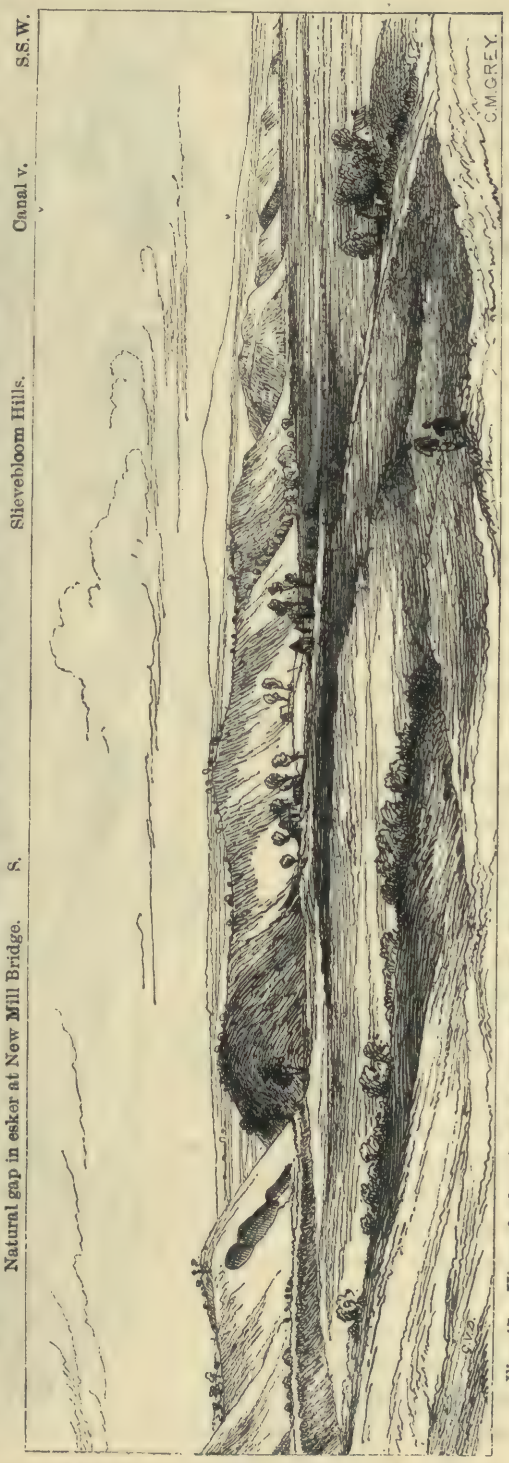

Natural gap in esker at New Mill Bridge.
S.
Slievebloom Hills.
Canal v.
S.S.W.
C.M.GREY.

Fig. 47. View of esker from Rahugh Moat, Co Westmeath. On turning to the south the gap south of the gravel pit near the left of the sketch is the gap by which one of the head waters of the Silver River escapes.

material which the farmer tills—the soil—and that derivable from the rock which the soil helps to conceal, even in Drift-covered areas.

Eskers.—These are, indeed according to the meaning of the term, remarkable *ridges*, and knolls of Drift, consisting of stratified sands and gravels with layers of clay, which traverse the central parts of Ireland from east to west, and are found as far north as North Londonderry and Mid-Antrim. They have been described and mapped in detail by the members of the Geological Survey; and have been treated of both collectively and in detail in a paper by Professor Sollas, F.R.S.* The following illustrations of these mounds have been drawn from the Survey Memoirs—the first two (Figures 47 and 48)† showing how the eskers appear in the landscape of their locality, the third (Fig. 49)‡ representing in plan,

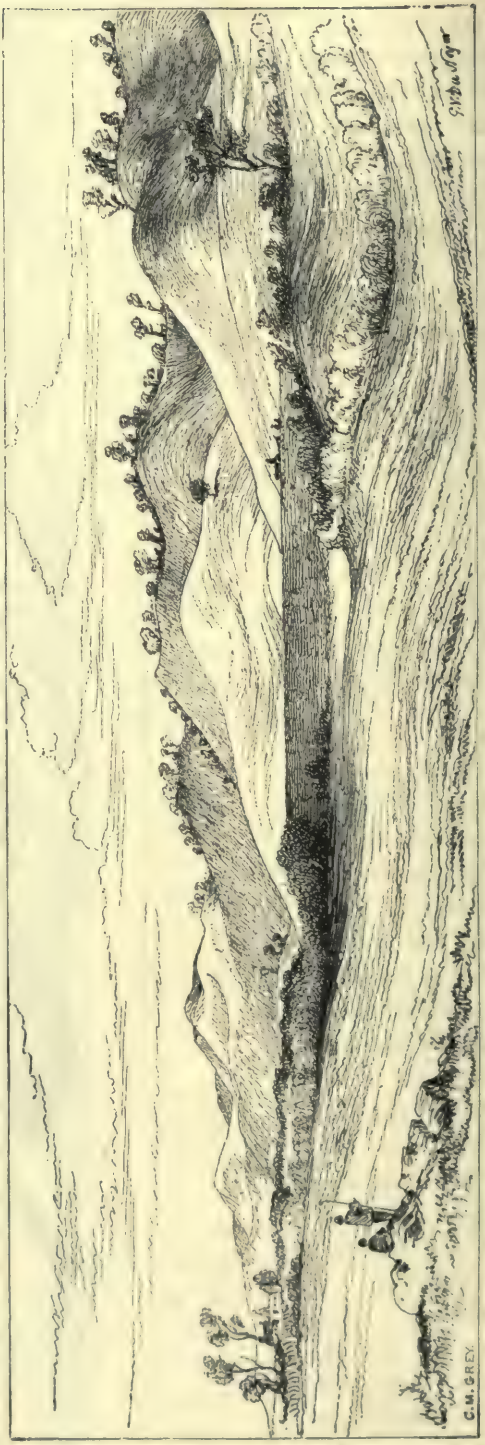


Fig 48. View of the Ballyduff and Newtownlow esker, looking north, from a point a little west of Newtownlow, three miles E. of Kilbeggan.

---

* Scientific Transactions of the Royal Dublin Society, vol. V. (series II.), 1896, p. 785.

† From Explanation of Sheets 98, 109; pp. 31 and 32.

‡ From Explanation of Sheets 98, 109; p. 33.

the manner in which ridges sometimes run together to form a compound esker.

Professor Sollas has followed the leading Scandinavian glacialists

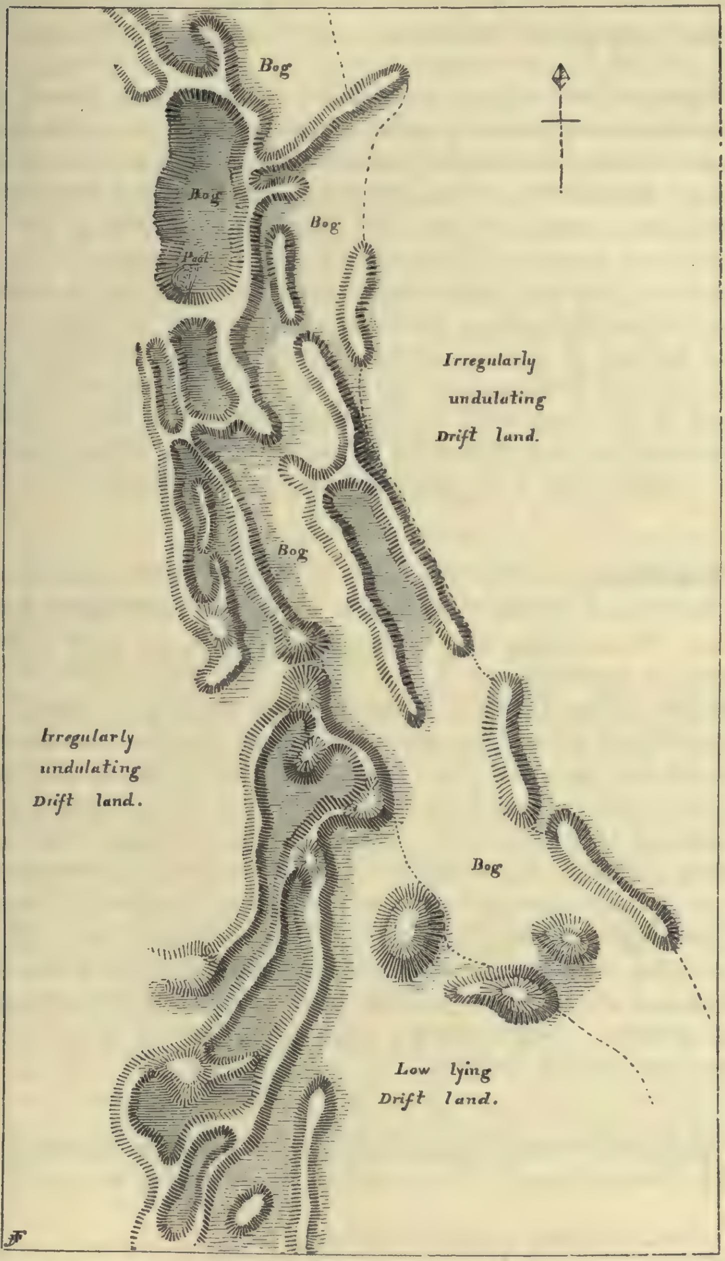

Bog
Bog
Pool
Bog
Irregularly undulating Drift land.
Bog
Irregularly undulating Drift land.
Bog
Low lying Drift land.

Fig. 49. Plan of eskers on the west side of the village of Streamstown, Co. Westmeath, Sheet 99. Scale, 6 inches to 1 mile.

in attributing the existence of eskers to the accumulation of sandbanks, and pocket fillings, in the water-courses and caverns of the great ice-sheet when melting. Such a hypothesis would necessitate the inference that the eskers were deposited equally with the higher-lying gravels contemporaneously with the Boulder-clay.

Professor Hull regards those ridges as having been formed by marine currents during a period of submergence, when the Irish area was again emerging, and subsequently to the deposition of the Upper Boulder-clay, while acknowledging that they are strewn with large erratic blocks.* Mr. Kinahan sets forth a similar view, and speaks of "bar-eskers" and "shoal-eskers." It is doubtful whether sea banks would have such steep sides and narrow summits as these ridges commonly present; and the thin layers and lenticles of clay interstratified with the sand in eskers, are sometimes so broken and contorted that only an unequal settling down of the ridge, when formed, could account for them; † these conditions are very improbable in marine deposits, but are exactly what would occur if the sands had been banked against ice.

Moraines.—Amongst the latest evidence for glacial conditions in Ireland are moraines, which are to be seen in nearly every hilly tract. These consist of a promiscuous mixture, or more or less stratified accumulations of sand, gravel, and stones, deposited in the form of banks—*lateral* moraines—along the sides of valleys; or as knolls and ridges lying across the valleys, when they are known as *terminal* moraines. The small snow-field which covered the central portion of each mountain group during the decline of glacial conditions in Ireland, sent forth glaciers which made their way outward through the valleys for various distances. These received, from the valley sides, materials which they bore along and deposited on melting in the form of moraines. Glaciers of two or more valleys coalescing, occasioned the formation of central moraines, which the compound glacier left as hillocks, or transverse mounds, along the valley bottom, each marking a stage in the glacier's recession till the ice ultimately vanished.

Moraines frequently dam the drainage of mountain districts and form lakes or tarns. This mode of lake-formation is usually to be seen at the heads of valleys where small lakes occupy the bottoms great semicircular hollows in the mountain sides, known as cooms.* What the origin of these immense recesses has been it is difficult to understand. They are by some attributed to glacial erosion. The late Rev. Maxwell Close, in an interesting paper on "Some Corries and their Rock-basins in Kerry," seems to have believed that their formation is due to the accumulation of drifted snow in recesses already, to some extent, formed.† The accumulation —renewed season after season prior to the entire disappearance of glacial conditions—compressed and solidified into ice—sinking *within*, with great and increasing pressure on the sides and bottom of the coom, and wasting *without* where the comparative lightness of the ice-foot would admit of its ascending over already-formed moraine—would operate with spoon-shaped gouging action, thus carrying away quantities of frost-loosened *débris* from the sides of the coom, *especially near the bottom;* and this, in proportion to the duration of the process, and the magnitude of the snow and ice accumulation. A striking instance of a moraine-formed lake is that of Glendalough, in Wicklow. With the moraine is associated, in this as in many other instances, a great assemblage of angular blocks which tail out from it along the valley downwards— and would seem to show that the distribution of these blocks, and the formation of the coom, are attributable to the same cause.

---

* "Physical Geology of Ireland," 2nd ed., p. 127.

† Masses of ice enclosed and subsequently melting in the eskers—a probable circumstance according to the previous hypothesis—would also aid in accounting for the unequal settling.

---

* Or, *corries* (*coire*, Gaelic = cauldron); or *cirques* (Fr.).

† Jour. Roy. Geo. Soc., Ireland, Vol. xii., 1867–70, p. 236. The cooms often occur on opposite sides of a ridge, with but a narrow col between. Instances occur in Kerry, and the writer has met with good examples in the Cor Slieve range east of Ballycroy in Mayo, and in Slieve League, in Donegal. A cause which the writer ventures to suggest for the initial recesses mentioned above is the rush of water from a melting ice-sheet, against the ridge. Taking the case which seems the most perplexing, above described—cooms occurring on opposite sides of a ridge—let us suppose, as is known to have been the case, that the ridge was deeply buried in ice, and that a river had established itself upon the ice plain above. As the general level of the ice lowered, the ridge would appear, the river be severed, and the water on the up side, find an exit along by the ridge after impinging upon it. The former direction of flow would continue, and by direct impact hollow out the recess. On the down side, the general level of the ice would drop towards the ridge where the melting would be most rapid; the river that flowed *away* from the ridge formerly, would now flow towards it, as would the river on the up-side of the ridge, so that hollowing would proceed on both sides; and be pronounced, in proportion to the directness, force, and prolongation of impact of the currents.

One would be tempted to attribute the recess on one side of a ridge to the erosion of a former waterfall tumbling over the crest from a supraglacial river on the upstream side, were it not that in this case a "dry gap" across the ridge above the recess would be almost a necessarily accompanying feature. The erosion of cooms in this manner may have taken place in some instances.

CHAPTER XII.

PEAT AND ALLUVIUM.

Peat, as stated in the opening chapter, is almost entirely composed of organic matter—the remains of plants in various stages of decay. Amongst the substances which form the decomposing aggregate, may be distinguished the remains of mosses, rushes, sedges, coarse grasses, reeds and heaths, as well as the bark, nuts, fir-cones, trunks and roots of trees, and occasionally also animal remains. Reference to the accompanying map will show how large an aggregate area is covered with bog and alluvial deposits—that of peat has been estimated at from one-seventh to one-tenth of the entire surface of the country. Deposits of so wide an extension, and affecting the well-being of a large section of the agricultural community, may claim a somewhat exhaustive reference in this place.

The humidity of the climate in the British Isles, particularly in the northern part of Britain and in Ireland, has favoured the growth of peat-forming plants. The higher grounds are frequently swathed in fog and mist, which afford copious supplies of necessary moisture. The supplies, however, are more or less intermittent, and, on steeply sloping grounds where drainage is rapid, they are scanty; as a consequence, the peat accumulates slowly on slopes, in comparison with the rate at which it forms in favourable situations in the low lands. On the flat parts of the high ground the peat attains considerable thickness; but it does not seem to accumulate as quickly as on the low ground.

Peat-filled Hollows.

In the low grounds, most of the peaty deposits—Red Bogs—occupy the sites of former lakes or expansions of rivers and their tributaries. The unequal denudation of the Central Plain, and the uneven distribution of the Drift, have left innumerable hollows which were originally filled with water. The margins of these lakes, and of the streams draining them, became lined with moss growths, which gradually encroached upon the water area, to the ultimate displacement of the latter in many instances. The choking of water-courses by vegetable growths, aided by fallen timber in some cases, caused a retention of the drainage, thus extending the areas of inland waters, as well as enlarging the areas ultimately occupied by marshes, swamps, and peat bogs.

The marls with freshwater shells, of frequent occurrence beneath the peat bogs of the Central Plain, afford corroborative evidence of the above conclusion, seeing that these must have been deposited in lake bottoms. Instances, too, have been met with, in which marl and peat occur in alternating layers, in a bog section, showing that the water areas here extended, and were followed by fresh growths of peat.

The following analyses indicate the large quantity of carbonate of lime present in the marls, and some clays found in the situations mentioned:—

TABLE OF ANALYSES—MARLS AND CLAYS.

Material and Locality.	Carbonate of Lime.	Carbonate of Magnesia.	Alumina.	Silica.	Bog Stuff.	Total.	Authority.
Marl under Timahoe Bog, ...	64	–	12	24	–	100	Griffith.
Blue and Yellow Clay under Timahoe Bog, ...	6	–	72	22	–	100	„
Blue Clay, Westmeath Bog, ...	44·4	1·4	27·2	27	–	100	Edgeworth.
White Marl, „ „ ...	87·3	–	1·1	·9	10·7	100	„
Blue Clay, „ „ ...	53·0	–	36	11	–	100	„
Marl, Aghaboe Bog, ...	85·0	–	7	8	–	100	Aher.
„ Cullena Bog, ...	46	–	32	22	–	100	„

Flats Bordering Lough Erne.

For examples of peat-formation under such circumstances, reference may be made to the low-lying districts around Upper Lough Erne, which present deep deposits of peat and alluvial clays, the *deepest* portions of which are much lower than the present water surface. Since the water escapes over a rocky bottom at Enniskillen it is evident that prior to the existence of bogs in the districts their place was occupied by an extension of the present lake, *i.e.*, to a width of about seven miles west of Lisnaskea, while the present lake is only three miles wide.

The Shannon also is margined by a large aggregate area of peat, in or about 176,000 acres from Lough Allen southward to the ocean, which would represent the former expansions of that river. Of the great "Bog of Allen," which covers a large part of Central Ireland, 151,000 acres have accumulated along the borders of the Shannon and its tributaries. The following illustration (Fig. 50)* which represents water-worn limestone blocks, eroded up to a certain height by the solvent action of former lake water, shows the level at which Lough Ree once stood—10 to 15 feet higher than its present summer height: the lake shore, moreover, is now some 300 yards distant.

---

* From Explanation of Sheets 98, 109, p. 10.

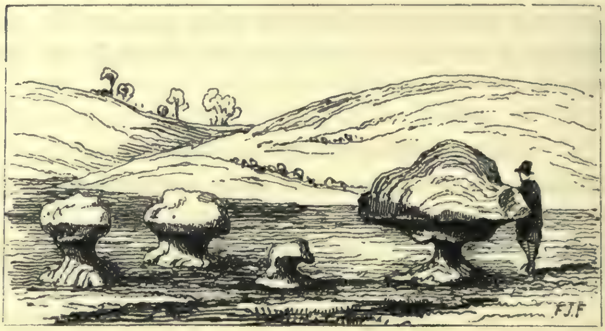


Fig. 50. Waterworn blocks of limestone showing former level of Lough Ree, near railway, in Cornaseer, W. of Ballybay. Ord. Sheet, Roscommon, $\frac{49}{1}$.

This and similar instances of water-worn limestone blocks, elsewhere, near Athlone, show that the lake waters once spread over a large area, probably over the whole of that now occupied by bog.

These bogs exceed 50 feet in depth in certain places, whereas those on the higher grounds seldom exceed 6 feet, though in mountain hollows and on flat high ground the depth may be much greater—12 feet has been mentioned by Mr. Nolan for some of the mountain bogs of Wicklow. Such depths graduate to much smaller thicknesses of peat when it clothes hill sides. As a consequence, the estimation and mapping of peat-covered areas can only be an approximation to exactitude. The Commissioners on Bogs on the ground of surveys carried out by Griffith, Nimmo, Edgeworth, Aher, and others, gave the following estimate for Red and Upland Bogs:—

Red Bogs, ...	1,576,000	acres.
Upland Bogs or Black Peat, . .	1,255,000	,,
Total, ...	2,830,000	acres.

The amount in each case has been considerably lowered since the drawing up of the Report,* bogs being entirely cut away in many places, and 2,000,000 acres,* may be a fair estimate of the area remaining at the present time—some included in "barren mountain land," in the annual Reports.

---

* Fourth Report, 1814, p. 16.

Rate of Growth.

The rate at which peat accumulates probably varies greatly, depending, as it does, upon geographical and other circumstances; these include, as we have seen, the situation; as also the underlying soil, drainage, and rainfall. Sir A. Geikie states that a layer 10 feet in thickness took 250 to 300 years to form, in Denmark, as against three or four feet in depth being formed in Switzerland in twenty-four years.† Satisfactory data bearing upon the subject are wanting in this country. The following case, however, may be given, in which a canoe was dug out of 3½ feet depth of peat, in the townland of Forest, north of Omagh. The deposit occupies the site of a small lake, in which an old man of eighty years, at the time the canoe was found, remembered to have fished; and about at the point where the discovery was made. The formation of peat in Ireland commenced in remote antiquity, possibly immediately after the disappearance of glacial conditions. Interglacial peat contained in and beneath boulder-clays has been noted in certain

---

* The following figures are given in the Department's Report of the Agricultural Statistics of Ireland for 1904. The Larger rivers, &c., from the Registrar-General's Report for 1897:—

Turf Bog and Marsh, ...	1,575,733	acres.
Barren mountain land, . .	2,208,528	,,
Waste land, ...	1,042,582	,,
[Larger rivers, lakes, and tideways, . .	492,252	,,]

The areas are distributed throughout the thirty-two counties, more than half of the bog, barren mountain land, and marsh being the following six, viz.:—

County.	Turf Bog.	Marsh.	Barren Mountain Land.
	Acres.	Acres.	Acres.
Cork, ...	25.637	67,456	239,944
Donegal, ...	101,852	30,008	359,042
Galway, ...	136,548	56,405	229,907
Kerry, ...	57,804	40,446	307,633
Mayo, ...	275.967	64,925	228.311
Tyrone, ...	44,199	11,234	97.789

† Text Book of Geology, 1st ed., p. 460.

places;* which seems to show that intermittent climatic conditions during the Ice Age were not prohibitive of vegetable life.

In sections of peat in upland and lowland bogs not only is stratification noticeable, but an obvious gradation downward, from the still-living more or less spongy vegetation above, to compact soapy matter beneath—from moss to black "stone turf"—in the latter of which only the most durable substances are recognizable, the trunks, roots, and bark of trees, and occasionally hazel nuts. The earliest-formed layer of peat is often devoid of timber, and may rest, especially in the lowlands, upon shell marl. The initiatory layer may, on the contrary, surround roots—stools of timber—rooted in the soil.

Oak and Fir.

Oak and fir are the principal timbers found in Irish peat; with these, however, are associated hazel, birch, yew, ash, and other varieties of wood. Mr. Kinahan states† that the growth of oak preceded that of fir, when both occur in the same section. Fir is frequently to be seen rooted in soils beneath the peat, and it may be observed to have flourished at successive levels of the deposit during its accumulation. Primeval forests of oak survive in various places at the present day in the west of Ireland, from which it may be inferred that in certain places oak, equally with fir, may have grown at various periods in peat bogs. In Denmark the growth of fir preceded that of oak.‡ Reeds and other strong water plants have also flourished at various levels in the peat, on the margins of springs in which some bogs abound, or according as detention of the drainage in certain localities, and consequent partial or extensive flooding, may have anew converted peat areas into marshes.

---

* The following excerpt from Mr. G. H. Kinahan's Article on the Soils of Ireland in the *Farmers' Gazette* of March 8, 1902, is interesting:—"On the Castlecomer tableland, at Newtown Colliery, Queen's Co., under 94 feet of drifts, three feet of peat was found by the late B. B. Edge, the peat being compressed into a lignite. In other places, also, at the outcrops of the coal seams, peat was found under the drift, but at what depth is not recorded. South of Castlecomer, in the Dinan River Valley, between Dysart and Coalcullen, there is a peaty accumulation under what seem to be glacial drifts ranging from 20 to about 60 feet in depth. In it the late Rev. James Graves found 'leaves, twigs, and sticks of alder and hazel, with nuts of the latter.' W. Tighe, in his statistic report, Co. Kilkenny, 1802, states that Mr. Prim, of Kilree, eight miles from Kilkenny, in sinking a pump hole, passed through 33 feet of drift, under which was 10 feet of bog, having timber at its base. A stick of the latter, sent up to the Dublin Society, was pronounced to be oak. Near Nenagh, Tipperary, Wilkinson records 'peat under 43 feet of boulder clay.' In the Boleyneendorrish valley, eastward of Gort, Co. Galway, under 25 feet of glacial drifts, there is a peaty and silt stratum in which were found 'cones of *Pinus sylvestris*, and *Abies excelsa*, fragments of wood, chiefly coniferous, portions of branches, scales of bark, hazel nuts, and the leaves and stalks of plants.'"

† "Geology of Ireland," p. 269.

‡ "Text Book of Geology," Sir A. Geikie, F.R.S. 4th ed., p. 607-8.

The Commissioners, in their (fourth) Report upon Irish Bogs, published an exhaustive memoir by Professor Wade upon the vegetable matters discernible in peat, and amongst the plants which he named are several species of mosses, lichens, ferns, heaths, shrubs, and trees, as well as grasses which naturally grow thereupon, and could with ease and profit be cultivated upon peat soils (p. 21).

Peat-forming Mosses.

The plants which form the largest proportion of peat are the mosses, the prevailing genera of which, as given by Wade, are—

Sphagnum,	yellow, green, and rose coloured.
Polytrichum,	great golden-hair mosses.
Hypnum,	feather mosses.
Bryum,	thread mosses.
Mnium,	spring mosses.

So important, in the circumstances, is this class of plants, that in many places the term *moss* is applied synonymously with *bog*. Thus, there are the Solway Moss, Lyth Moss, and Nitherslack Moss, in Westmoreland; Rowdsley Moss and Chat Moss, in Lancashire; Woolston Moss, in Cheshire, and so forth. Plants of the genus *Sphagnum* are by far the most important and abundant in species. Twenty species and forty-five varieties of the class Sphagnaceæ are described by Braithwaite; and Stewart and Corry record the occurrence of ten species, and eleven varieties of the class in this country.

These plants possess the property of being able to continue in growth and propagation above while decay proceeds below, so that individual plants form connecting links between the living and dead portions of a bog. The stems and leaves of Sphagna owe their sponginess to the nature of their fabric, this being made up of comparatively large cells devoid of essential plant juice—air cells—capable of imbibing through minute pores in the cell walls, and of giving up, a full complement of moisture. In virtue of the spongy structure of the mosses, they are, when dry, powerful absorbents of liquids, are consequently suited for litter, and serve well in other circumstances, as retainers of liquid manure. The microscopic structure of the mosses is recognizable even when decay has proceeded so far that the mass forms a dark brown turf; beyond this stage of alteration peat is not a good absorbent when dry.

Economic Applications.

Professor T. Johnson, D.SC., F.L.S., of the Royal College of Science, in an exhaustive paper on The Irish Peat Question,* compares the absorbent power of Sphagnum and some other substances in the following way (p. 6):—

Sphagnum absorbs of its own weight of water,	7-9 times.
Hypnum (moss of morasses), . . .	3 ,,
Straw, ...	3 ,,
Wood, wool, or sawdust, ...	3-4 ,,

It is thus seen that Sphagnum far surpasses other materials in this property. Unfortunately this family of mosses is not as plentiful as the other families: the extensive Bog of Allen seems to be "singularly deficient in good surface Sphagnum"; and the partially decayed layer of this great morass is not of the highest value for absorbent purposes. The same author states (p. 2) that the "nature of the flora is dependent on the kind of bog, whether the high peat-bogs, fens, or morasses. Sphagnum and heather are characteristic of the high peat-bogs, and are absent from the morasses, where the moss Hypnum, rushes, and sedges, are the chief representatives of the flora."

When decomposition has proceeded to an almost ultimate extent the organic structure is scarcely apparent under the microscope; the peat becomes black, and when dry is very hard, and of a high density—it is "stone-turf." The depth at which "stone-turf" occurs varies in different peat-bogs. On the higher grounds it may be less than 3 feet from the surface; in "red bogs" it may not be reached for a distance of 20 feet or more, downward. "Black turf" shrinks more than "white turf" in drying, a fact which, no doubt, is to be accounted for by the greater degree of cohesion existing between the shreds and particles of the peaty substance, when, indeed in proportion as, the cellular structure has become destroyed.† With a view to exhibiting the shrinkage which different qualities of peat undergo, two specimens were taken from Emlagh Bog some three miles west of Roscommon, one 3 feet from the surface—a light brown turf; the other 12 feet from the surface—dark brown; each specimen was made cubical in form, and contained 43·6 cubic inches; and each was weighed in the state of saturation in which it came from the pit, and set to dry. The results, after twelve days drying at 80° F., are given in the following table:—

---

* Economic Proceedings, Royal Dublin Society, No. 1.

† A writer in the *Farmers' Gazette* for January 26th, 1895, attributed the shrinkage of peat in drying to the gum-like substance *pectase*, which, the writer stated, not only causes shrinkage, but promotes drying, by squeezing the water from the interior to the surface. It is difficult to conceive how such an effect could be produced by the extremely small proportionate quantity of pectase existing in peat.

—	Original Bulk.	Bulk when Dried.	Loss per cent.	Original Weight.	Weight when Dried.	Loss per cent.
	Cub. in.	Cub. in.		Ounces.	Ounces.	
Light brown turf,	43·6	15·9	63·5	25·5	3·125	87 7
Dark brown turf,	43·6	12·9	70·4	25·5	3·75	85·3

Peat as Fuel.

The extensive use of peat as a fuel in Ireland justifies some notice of it in this regard, especially in view of the probability that it may come into more general use, in the compressed form, and thus become a valuable industrial product. In Crookes' and Röhrig's Practical Treatise on Metallurgy—Steel and Fuel" (Ed. 1870, pp. 401 *et seq.*), we are informed that Karmarsch ascertained the heating power of different kinds of turf as compared with that of pine wood to be in the following proportions, viz.:—

1,000 lbs. of yellow turf are equivalent to 946 lbs. of air-dried pinewood.
,, brown ,, ,, to 1,076 ,, ,, ,,
,, pitch (black) ,, ,, to 1,107 ,, ,, ,,
,, earthy ,, ,, to 1,040 ,, ,, ,,

Karsten found that 4 parts of turf by volume are required to replace 1 part of coal, for boiling; 2 lbs. to 2½ lbs. supply as much heat as 1 lb. of coal.

The heating power of turf depends upon the combustion of the carbon and hydrogen which it contains. The proportionate amounts of both in samples of Irish peat, as found by Sir R. Kane, are set forth in the following table taken from Percy's Metallurgy:—*

COMPOSITION OF PEAT (DRIED).

—	Cappoge.	Kilbeggan.	Kilbaha.	Phillipstown (1.)	Phillipstown (2.)	Wood of Allen (1.)	Wood of Allen (2.)
Carbon, ...	51·05	61·04	51·13	57·53	58·48	58·27	56·20
Hydrogen.	6·85	6·67	6·33	6·83	5·90	6·43	5·31
Oxygen, ...	39·55	30·46	34·48	32·23	31·47	31·33	29·84
Nitrogen,...	-	-	-	1·42	0·85	1·23	0·75
Ash, ...	2·55	1·83	8·06	1·99	3·30	2·74	7·90

---

* Edition 1875, p. 206.

The presence of ash, and especially of water, materially lessens the heating power of peat; for these accessory substances, as well indeed as nitrogen, act as heat absorbents rather than as heat givers. The net heating power, therefore, is the fixed quantity of heat given out in the combustion of the hydrogen and carbon in a certain weight of peat or other fuel, *less by* that absorbed by the contained non-combustible substances. The absolute heating power of different kinds of turf, wood, and charcoal was calculated by Tunner, and is given by Crookes and Röhrig as follows:—*

Dry turf without ash, absolute heating power	0·65
,, with 4 per cent. of ash, absolute heating power	0·63
,, ,, 12 ,, ,, ,, ,,	0·58
,, ,, 30 ,, ,, ,, ,,	0·45
Turf with 25 per cent. hygroscopic water, absolute heating power	0·47
,, 30 ,, ,, ,, ,,	0·41
,, 50 ,, ,, ,, ,,	0·27
Dry wood ,,	0·47
Wood with 20 per cent. ,, ,, ,,	0·36
Charcoal with 18 per cent. hygroscopic water ,,	0·87
Dry charcoal (about 3 per cent. ash) ,, ,,	0·97
Carbon	1·00

Compressed Peat.

According to Phillips,† 1 lb. of dry turf will evaporate 6 lbs. of water; air-dried peat, however (which contains about 20 per cent. of water) will not evaporate more than 4 lbs., while 1 lb. of coal evaporates about 8 lbs. The chief disadvantage of peat as a fuel is its bulk. Its specific gravity ranges from ·11 to 1·03, while that of coal varies from 1·05 to 1·50. Some forms of black or "stone" turf are almost as heavy as light coal. To meet the disadvantage as regards bulk various means of compressing peat have been proposed from time to time: the "dense" peat so formed reaches as high a specific gravity as 1·52,‡ and is well adapted for use in locomotive engines, and other purposes where it is necessary to economise space. The cost of transit in Ireland, added to the expense of production, militates against its general use. A serious drawback to the production of peat fuel on a large commercial scale, is the comparatively short period, annually, which our moist climate affords for air-drying.

The peat in certain places is highly inflammable: when dry it burns with a sustained flame, and is known as "candle or gas turf." Of such David Aher wrote* as follows:—"The peat immediately in contact with the fir is denominated 'greasy turf,' and forms a stratum about 2 or 3 feet thick; it is very inflammable, and burns rapidly with a bright flame, leaving very little residue. This bituminous property it receives from the great mass of fir trees which are embedded in it, and are most copious in the deposit of turpentine, giving a whitish colour to the peat. This turf is only found in the vicinity of these trees, seldom extending for more than a foot above and below the roots."

---

* *Supra cit.*, p. 403.

† "Metallurgy," edition by Bauerman, 1887, p. 404.

‡ Percy's "Metallurgy," 1875, p. 235.

Peat Products.

Amongst the economic uses to which peat and its products are now applied † may be mentioned *fibrous peat-litter*, the imported preparations of which do not equal, as absorbents, fresh peat-moss litter after Sphagnum; *peat-wool*, used with a mixture of sheep's wool or cotton for the manufacture of coarse fabrics; *peat-mull* or peat powder, used in making fire-lighters and briquettes, and for sanitary purposes; also for egg-packing. Peat-mull is also used mixed with molasses as a fodder, with more or less success. Several other economic products such as tar, oils, alcohol, ammonium sulphate, &c., may be obtained by comparatively inexpensive processes.‡

Bog Iron-Ore.

Deposits of bog iron-ore are frequently to be met with in Irish peat-bogs. The ore, being largely composed of oxide of iron, and when dry presenting this substance in finely divided form, is of great value in the purification of gas. The oxide is spread out in chambers, over which the gas in its crude state from the retorts is passed; from this the oxide takes up sulphur and other impurities, and leaves the gas uncontaminated by these substances. The "spent" oxide is then valuable (even more so than the original oxide) as a source of sulphur, ammoniacal salts (some 18 per cent.), and small quantities of Prussian blue and bisulphide of carbon.*

---

* Third Report of Commission on Irish Bogs, p. 63.

† "The Irish Peat Question," pp. 12, *et seq.*

‡ "Sooner or later Ireland must make something of her enormous peat supplies. A factory has been erected at Strangfjorden, in Norway, for the treatment of peat by electricity and obtaining from it gas, tar, oils, charcoal or coke, paraffin, ammonium sulphate, and methyl alcohol. Twelve retorts are in use, and one hundred tons of peat can be treated daily. The method is known as the Jebsen process, and it is contemplated at an early date to set up a plant in the Emerald Isle, where there is plenty of peat and sufficient water-power to drive the turbines or the production of the electric energy. Ireland, above all things, needs *diversified industries.*"—*Daily Telegraph.*

The iron-ore is a result of double decompositions which take place in soils and subsoils, and even in the underlying rocks undergoing disintegration, in presence of organic matter—*humic*, *crenic*, and *apocrenic* acids, and air and water. By such natural agencies silicates of iron are dissolved out of the subsoils and rocks beneath peat; ferrous sulphides—iron pyrites—are oxidized and converted into sulphates; and the substances in solution are converted into carbonates. These through further oxidation become broken up, the carbonic acid escaping; and the resulting oxide, in a hydrous form, becomes deposited from springs which come up through the bog from below.†

Bog Springs.

Highly decayed peaty matter being heavier than water, bulk for bulk, and fresh, slightly decayed mosses lighter, surplus water in comparatively level bogs accumulates between the heavier peat below and the spongy mass above—the lighter portions of the peat mingling with the water to form semi-liquid mud. In these circumstances the spongy mantle forms an envelope which retards the escape of the water; and, when the latter accumulates more rapidly than it can pass off by oozing through the mantle, the bursting of the bog at some point of weakness on its lowermost margin is liable to, and occasionally does, ensue, with disastrous consequences. Parts of the country, through which the drainage of those bogs ordinarily flows, thus sometimes become devastated by deluges of fluid mud.

---

* The following notes upon Bog iron-ore have been supplied to the writer by Mr. John Wilkinson, of Falcarragh, Co. Donegal, who has had long experience in the exportation of this economic product:—"From the small shipping port of Ballyness, near Falcarragh, there were fully 80,000 tons shipped between 1864 and 1882. The average price of this was 10*s*. per ton free on board," which is about the current price at the present time. "From the districts of Teelin, Inver, Mountcharles, and Donegal (town), 50,000 tons have been exported during the past thirty years, and 100,000 tons from Moville, Culdaff, Dunaff, and Buncrana. The districts of Killygordon, Letterkenny, Rathmelton, and Rathmullen, in Donegal, and those of Tullamore, Mountrath, Cush, Athboy, and Ballina, have also yielded large supplies. The deposits generally throughout the country have largely been drawn upon, especially those along the sea-board for a distance of twelve to twenty miles inland; so much so that here the oxide may be regarded as well-nigh exhausted. It is hoped that the new light railways in Donegal may be the means of remuneratively tapping other deposits.

"The deposits are usually 2 to 4 feet in thickness, though they sometimes reach 6 to 9 feet in depth. The substance is generally light gray in colour, though by exposure (and oxidation) it changes to deep red or brown.

"The ore is shipped to Antwerp, Rotterdam, Dunkirk, and a good many other French ports, and some to Spain.

"In 1874, a company was formed in London—the promoters being Irishmen—with a share capital of £150,000, to deal exclusively in Bog ore. This company has supplied the leading gas companies of the United Kingdom, France, and the Netherlands since it started, and still does so." It is the Gas Purification and Chemical Company, Limited.

† Some interesting remarks on the subject of Bog iron-ore and allied deposits will be found in Part I. of "Applied Geology," by J. V. Elsden, B.SC. (Lond.) pp. 78 to 82.

Rain water descending upon the surface of a bog is of itself not sufficient to produce such results; that which falls upon the immediately adjacent upland, usually passes away around the bog-margins; but if the drainage basin be large, and facilities for escape inadequate, the water may accumulate; and it is known that springs exist in the interior of many bogs.* Such are outlets or underground channels into which descend the drainage of perhaps considerable areas, distant, it may be, from the bogs and at higher levels—circumstances which are very common in limestone districts. The quantity of water entering these channels in rainy seasons, or otherwise accumulating in the peat, may be so great as to endanger the stability of bogs. The existence of the springs promotes rapid moss growth in their vicinity, so that the central portions of low-lying bogs are frequently more elevated than their margins, which induces a considerable outward pressure. This condition has been described as follows by the Commissioners on Bogs: †—"The summits of bogs are generally deepest and invariably the wettest parts. . . . . Springs are often met with in the deepest part of the bog. The wetness of the bogs originates from springs within themselves."

Bog-flows and Mud-deluges.

Much interesting information upon the bursting of bogs, and bog-flows, was collected and published, upon the occasion of a late catastrophe in Kerry (29th December, 1896), when a mud deluge swept down the Owenacree Valley from the Knocknageeha Bog. The catastrophe was, unfortunately, attended with loss of life, and the devastation of some 300 acres of profitable land. A still more recent catastrophe, occasioning the loss of two lives and much damage to arable land, took place on the 10th October,1900, within a short distance of Ballaghline, in West Clare. The bog which gave way, and in part flowed as liquid mud along the valley, was situated between Lakes Doonagera and Luogh at an elevation of 400 or 500 feet. The causes of such disasters are discussed in the Report‡ mentioned in the footnote, prepared in connection with the former event, and an exhaustive summary of previously recorded bog-flows in Ireland is therein presented. From this

---

[*] See Third Report, Commission on Bogs. Appendix iii., p. 60.

[†] Third Report. Appendix ii., pp. 65, 66.

[‡] Of Committee of the Royal Dublin Society, prepared by Professor Sollas, F.R.S., and Mr. Praeger, B.E., M.R.I.A., 20th January, 1897. Sci. Proc., Vol. viii., N.S., Part 5, page 475. An interesting Summary was also given by Mr. G. H. Kinahan, in *Farmer's Gazette*, February 13th, 1897.

Report the following epitome has been prepared, giving the leading particulars of agricultural interest:—

Bog-flows in Ireland.

A.D. 1697, June 7. Kapanihane Bog, Co. Limerick, near Charleville; meadow and pasture adjoining the bog moved over similar valuable land, and was followed by a mass of the bog. Thereupon the "rising" in the middle of the bog sank flat.

1708. Castlegarde Bog, County of Limerick, moved along a valley, burying houses and twenty-one persons. It was one mile long, a quarter-mile broad, and about twenty feet deep in some parts; and ran for several miles.

1745. March 28. Bog of Addergoole, Dunmore, Co. Galway. Ten acres of bog moved down a stream course, covering thirty acres of pasture by river-side, and by damming the water destroyed some 50 or 60 acres besides.

1788. March 27. Bog near Dundrum, Co. Tipperary. A large bog, 1,500 acres, burst, deluging with mud a vast tract of fine fertile land.

1809. Dec. 16. Bog of Rine, Camlin river, Co. Longford. "Twenty acres of bog burst asunder in numerous places." The *débris* dammed the drainage so as to submerge 170 acres, which were relieved of water only at the cost of a large outlay.

1819. January. Owenmore Valley, Ennis, Co. Mayo. The overflow of a mountain tarn occasioned the bursting of a great bog which confined the waters of the lake. The bog carried with it boulders and bog timber, besides the stones, roofs, *and inhabitants* of houses which formed a small hamlet.

1821. June 19 and 26. Kilmaleady Bog, near Clara, King's County, 500 acres in area, and 40 feet deep in parts. Part of this bog moved three miles, and covered, after moving, about 150 acres. Another account, regarding the occurrences of the second date, June 26, states that the bog moved "at the rate of about two yards an hour, with a front of 200 yards wide and about 8 feet deep."

1870. Dec. 14. Tulla Bog, near Castlereagh, Roscommon. The deposit of mud left upon the low ground extending six or seven miles along the valley of the Suck, covered 165 acres.

1873. Oct. 1. A bog, three miles to the east of Dunmore, Co. Galway, slowly moved down the valley of the Dunmore river, burying three farm-houses and covering 300 acres of pasture and arable land 6 feet in depth.

1883. Jan. 25. A bog between Moor and Baslick, near Castlereagh, Roscommon. Consequent upon the bog-flow 4,000 acres of land were covered; three houses had to be deserted, and several roads were blocked, the Ballinagare road being covered to a depth of 15 feet.

1883. Jan. 30. A bog near Newtownforbes, Co. Longford, as stated by the *Freeman's Journal,* commenced to migrate, covering turf and potatoes.

1890. Jan. 27. Bog at Loughatorick North, Co. Galway, covered with peat an area of 100 acres, to a depth of 12 inches, the upper part of the bog subsiding 10 or 12 feet.

1895. August 9. Dungiven Bog, Co. Derry, 10 to 30 feet deep, burst and flowed down-stream without doing damage, the gradient being steep—one in twelve in the bog itself—and the adjoining land not being under cultivation

Conservation of Bogs.

Having regard to the foregoing record, it is of obvious moment that attention should be given to the conservation of peat bogs in this country, as much with a view to averting damage to useful land, as to guarding from waste a valuable and not inexhaustible fuel supply—in those districts where mud deluges are liable to occur. Methods of preventing these have been discussed from time to time since Dr. Gerard Boate dealt with the subject; and the drainage of peat-bogs received a good deal of attention in the first half of the last century. Shallow cuts are sufficient to discharge the rain water falling upon the bog surface; when, however, springs rise from concealed channels, the problem of drainage presents this difficulty, that deep drains, run through the bogs to tap the springs, rapidly fill up with sludge, and might in wet seasons initiate catastrophies. The method advocated by Mr. G. H. Kinahan,* following the suggestion of Boate,† is probably the best means of achieving the desired object. This is to open moderate cuts from the lowest-lying margin towards the centre, extending them little by little yearly. Such considerations as these are of importance in planning attempts at bog-reclamation, for thorough drainage is an essential preliminary to success in such projects, whether small or large.

---

* *Farmers' Gazette,* March 27th, 1897.

† Rather described by Boate as having been practised by the English in Ireland prior to his visit in 1755.—See "Natural History of Ireland," p. 65.

Submerged Peat.

Submerged, and partially submerged peat occur at various points along the coast. On the Antrim coast, bogs are from time to time laid bare, as off the West Strand, Portrush; and near Bangor, on the Down coast, the same fact is to be observed. At the mouth of the Gweebara[*] river, in Donegal, peat exists covered at high water; and in Dawros Bay[†] a bog, which contains fir roots and stumps, is submerged to an extent of 14 feet at high water. At Renvyle, in North Galway, peat is known to occur beneath the water which separates Crump Island[†] from the mainland. In Galway Bay, particularly bordering the Aran Islands, bogs are traceable below the low water of spring tides. In Dunworly Bay, near Clonakilty, peat was bored through for 50 feet below the sea level without reaching the bottom.[‡] Near Tramore, in Co. Waterford, peat forms the sea bottom at the four-fathom line;[§] and in the lagoon formed by a sandbank stretching eastward from Tramore, it has accumulated to a great depth. It also occurs, with oak stumps in position, at Duncannon in the Suir estuary, at low water of spring tides.

Alluvium.—The mode of formation of alluvial deposits was described in the opening chapter. They have been laid down by flowing water, and their physical characters have been determined by the rates[||] at which the water carrying the detritus moved; and their chemical constituents (and thus their agricultural value to a large extent) are also determined by the nature of the ground traversed by the drainage. To describe these deposits in detail would be an impossible task in a work of this kind. They vary greatly in character, from the finest clay and mud to the coarsest gravel and shingle. Some have been laid down by streams and turbulent watercourses, no longer visible; some by the former representatives of the present rivers and streams, when they flowed

---

[*] Explanation of Sheets 15 and 23.

[†] Explanation of Sheet 83.

[‡] Explanation of Sheet 187, 195, 196

[§] G. H. Kinahan, *Farmers' Gazette*, 8th March, 1902.

[||] David Stevenson, in "Canal and River Engineering" (p. 315), gives the effect of moving water on different materials in substance as follows:—A current of

3 in.	per sec.	= 0·170	mile per hour,	moves	fine clay.
6 in.	,,	= 0·340	,,		fine sand.
8 in.	,,	= 0·454	,,	,,	sand as coarse as linseed.
12 in.	,,	= 0·682	,,	,,	fine gravel.
24 in.	,,	= 1·364	,,		pebbles 1 inch diameter.
36 in.	,,	= 2·045	,,		angular pebbles, size of an egg.

at levels higher than those they now occupy. On detailed maps it is possible to distinguish old-river deposits from those more recently formed; and going still further back, we may discover and map out those which were laid down by waters issuing from the melting ice of the lowlands and hills, when it was finally disappearing from the face of the country—"Glacial-flood-gravels," &c.

The rivers and streams of Ireland, especially in flood, carry much peaty matter in suspension; it is also obvious that the clay and sandy portion of the silt, as well as the mineral matters in solution which the waters carry, are dependent for agricultural quality and worth upon the rock formations over which the waters flow; that is to say, upon the Formations represented in the drainage area or catchment basin of each stream or river. We may indeed say that most of the alluvial deposits throughout the country should present a favourable admixture of organic matter and sandy loam, endowed with variable quantities of fertilizing substances.

Drainage Areas.

If the reader will take a good map, and draw thereon a line separating the head waters and tributaries of any stream or river-system, from those which do not find their way into it, this line will enclose the drainage area of the water-system in question; and the portion of the line which separates two adjacent stream or river-systems constitutes their *watershed*—in other words, their water-division. The following Table has been drawn up with a view to showing the geological Formations (other than Drifts and Bog) comprised in the drainage areas of the principal Irish rivers and tributaries, commencing at the north. The Formations traversed by the head waters of the main stream are placed first; similarly those washed by the head waters of the tributaries; then the Formations crossed lower down the courses, both of the tributaries and the main streams. The silts and solutions contained in the latter, below their junctions with the tributaries, will of course derive materials, silts, &c., from the tributaries:—

Table of Formations (other than Drifts and Bog) traversed by the Rivers of Ireland and their Tributaries.

Rivers.	Formations, &c.	Tributaries.
Foyle . .	Old Red Sandstone, .	Strule.
	Granite, . .	
	Metamorphic rocks, .	
	Lower Carb. Sandstone, .	
	Granite, .	Finn.
	Metamorphic rocks, .	

Rivers.	Formations, &c.	Tributaries.
Bann,	Granite.	
	Silurian.	
	Old Red Sandstone,	Blackwater.
	Lower Carb. Sandstone,	
	Trias,	
	Upper Carboniferous,	
	(?) Pliocene, or Eocene,	
	Chalk.	
	Basalt.	
Lagan,	Silurian.	
	Chalk.	
	Trias.	
	Basalt,	Collin R.
Erne,	Silurian,	Annalee.
	Granite.	
	Lower Carb. Sandstone,	Colebrooke R.
	Carb. Limestone,	
	Old Red Sandstone,	
	Lower Carb. Sandstone,	
	Upper ,, ,,	
	Carb. Limestone,	
	Upper Carb. Sandstone,	Swanlinbar R.
	Carb. Limestone,	
	Metamorphic rocks.	
Boyne,	Silurian.	
	Carb. Limestone.	
	Upper Carb. Shale.	
Moy,	Silurian.	
	Lower Carb. Sandstone.	
	Carb. Limestone.	
	Upper Carb. Shale.	
	Metamorphic rocks.	
	Granite.	
	Carb. Limestone.	
Corrib,	Silurian.	
	Metamorphic rocks.	
	Granite.	
	Carb. Limestone,	Robe River.
	Old Red Sandstone,	Clare-Galway R.
	Carb. Limestone,	
Shannon,	Upper Carb. Sandstone.	
	Carb. Limestone.	
	Old Red Sandstone.	
	Lower Carb. Sandstone and Shale.	
	Silurian.	
	Carb. Limestone,	Suck.
	Old Red Sandstone,	
	Lower Carb. Sandstone,	

Rivers.	Formations, &c.	Tributaries.
Shannon,	Carb. Limestone,	Clodiagh River. Brosna River.
	Silurian,	Nenagh R.
	Old Red Sandstone,	
	Carb. Limestone,	
	Old Red Sandstone,	Maigue.
	Carb. Limestone,	
	Upper Carb. Sandstone,	Deel.
	Carb. Limestone,	
	Old Red Sandstone,	
Liffey,	Granite.	
	Silurian.	
	Carb. Limestone.	
Avoca,	Granite,	Avonmore.
	Silurian,	Avonbeg.
	Felsite,	Derry Water.
Slaney,	Silurian,	Derry River.
	Granite,	Urrin R.
	Felsite,	Boro R.
Barrow,	Silurian,	Nore.
	Old Red Sandstone,	
	Carb. Limestone,	
	Upper Carbon. Sandstone, Shale, &c.	
	Limestone.	
	Granite.	
	Silurian.	
Suir,	Silurian.	
	Old Red Sandstone.	
	Upper Carb. Series.	
	Carb. Limestone.	
Blackwater,	Upper Carb. Series.	
	Old Red Sandstone.	
	Silurian.	
	Carb. Limestone.	
Killarney River,	Old Red Sandstone.	
	Limestone.	
	Upper Carb. Series.	
Lee,	Old Red Sandstone.	
	Lower Carb. Grits.	
	Carb. Limestone.	
Bandon River,	Old Red Sandstone.	
	Lower Carb. Grits.	
	Carb. Slate.	

Arterial Drainage.

Callows, corcasses, holms or "bottoms" throughout Ireland have been relieved of excessive water to a great extent within recent times. Many marshes have been dried, and bogs in many places have received increased outlet for their moisture through the lowering of their channels of discharge. This improved state of the country's drainage is doubtless traceable in some degree to natural causes, even since the country has become inhabited, through the perpetual eroding action of streams and rivers upon their beds. In this manner, doubtless, has come about the great fall of the waters of Lough Ree, mentioned on a previous page, the rocky bed at Athlone having given way to erosion. The necessity for artificial drainage, however, became so much felt in the early part of the last century, that Government Commissions were formed to report upon cases where works of this nature should be undertaken. Many vast schemes of arterial drainage were reported on and adopted during the years 1843 to 1850, as well as other schemes, which concerned the thorough drainage of estates. These were recommended because, though costly, it was estimated that the outlay would be recoverable in the increased value of the lands drained.

As showing the scale of these undertakings, a few figures may be given as follows:—In 1843 and 1844 ten schemes were reported on, the affected flooded and injured lands, varying in extent up to 5,948 acres. Again, in 1845, while some of the previous schemes were advised to be enlarged, five new ones were reported upon and recommended, showing acreages and location according to the subjoined list, given to exemplify the detail:—

Upper Boyne District,	Westmeath,	1,135	acres.
	Meath,	2,719	,,
	Kildare,	1,240	,,
	King's County,	1,965	,
Fane District,	Louth,	1,149	,
Borris-in-Ossory,	Queen's County,	2,023	
	Tipperary,	1,209	,
Roe District,	Londonderry,	2,863	,,
Ballinamore and Ballyconnell District.	Cavan,	2,268	,,
	Fermanagh,	566	,,
	Leitrim,	3,419	,,
	Total,	20,556	acres.

As many as sixty-eight schemes were reported upon in the following year, 1846, one of which alone concerned the draining of 260,480 acres in the district of Loughs Oughter and Gowna, and Upper Erne river. Other schemes of great importance were also brought forward the same year, including the drainage and improvement of 26,000 acres around Lough Neagh, 20,972 acres bordering Lough Corrib, in Galway and Mayo, and 15,800 acres in the Ferbane district in King's County.

Further drainage works were recommended in 1847, in which were involved relief from flood-waters and the improvement of 129,540 acres, in areas scattered over twenty-seven counties; besides 3,333 acres recommended for thorough drainage in Antrim. Many other schemes have since been carried out; the above figures will, however, suffice to show the large acreage which was prejudicially affected by surplus water prior to 1843. The Parliamentary Report for 1851 gives the "Return of all sums which have been allocated by the Treasury" for "the Promotion of Arterial Drainage in Ireland," up to February 28th of that year, to be £1,392,762. Loans to individuals by the Commissioners of Public Works amounted to £199,870 up to the same date.

Reclamation.

Were it admissible in the present work to discuss the reclamation of waste land—an agricultural topic—much would have to be said upon the question of outlay as compared with resulting profits. It may here suffice to state that of the aggregate area of some 1,500,000 acres, which seems to lend itself to utilization, many of the smaller tracts, as the map shows, are bordered by Drifts, which would supply abundance of gravel and boulder-clay for top-dressings. The limestone detritus also contained in much of the Drift would be a readily obtained source of lime for the reclamation.

Afforestation.—The re-afforesting of Ireland is a project which has had many advocates; and though the attempts to carry it into effect, in several places, have not been attended with such unvarying success as to sustain the enthusiasm which some have indulged, there are still many whose convictions and hopes remain unshaken, influenced, on the one hand, by a belief in the great advantages of many kinds which would accrue to the country, and on the other by the very just lament that so wide a scope of waste land is not in some manner utilized. Only about 310,000 acres, of bog and upland, are at present under woods and plantations, not one-sixty-fourth part of the country's area. A valuable lecture upon the subject was delivered before the Royal Dublin Society* in March, 1899, by W. R. Fisher, B.A., Assistant Professor of Forestry, at the Royal Indian Engineering College, Cooper Hill, which furnishes a good summary of the advantages, possibility, and means of carrying out projects of the kind. From this lecture the following notes have been extracted:—

* "Economic Proceedings," Royal Dublin Society, Vol. I., Part II

Demand for Timber.

Great Britain imports every year about 9,000,000 loads of wood, worth £20,000,000 annually, and £6,000,000 worth of other forest produce, resin, wood-pulp for paper-making, &c., which, leaves a balance of £20,000,000, after writing off the £6,000,000 against 500,000 loads of hard woods, which could not be grown in these countries. This sum indicates the vast demand for timber alone, which it would be possible to meet at home, not to speak of concomitant outlays and earnings in rough-wood crafts, and in foresting, so as to place the timber on the market, all of which would, of course, contribute to the country's wealth. After exhaustive references to the planting, treatment, and renewal of forests, as well as to other details necessary for their successful growth, Professor Fisher makes the following reference to Ireland:—"The chief requirement of trees is plenty of moisture throughout the year, and in this respect our climate, and especially that of Ireland, is admirable. The winters are generally mild and short, and, in fact, the chief difficulties to contend with are strong westerly gales, and the occurrence of spring frosts up to May, and even June, which, however, are less felt in Ireland than in Great Britain, as the fuschia hedges in Westmeath[*] testify." The following notes upon the characters of timber to be grown are reproduced in full (p. 92):—

Profits from Afforestation.

> "Dr. Schlich has calculated that if a pine wood is grown for pit timber, starting with 3,500 plants an acre, the thinnings made at the age of twenty, twenty-five, and thirty years, will sell altogether for about £12 an acre, and will leave about 750 trees per acre, which at the end of forty years will be 51 feet in height and 6½ inches in mean diameter, representing a volume of about 3,200 cubic feet per acre (quarter-girth measurement). This at 5*d.* a cubic foot is worth £66; and allowing £6 for planting, and 3*s.* a year for rates, maintenance, and supervision, at compound interest at 2½ per cent., corresponds to a soil rental of 13*s.* an acre annually.[†]

---

[*] And even in West Donegal, we may add.

[†] The data here presented as the basis of Professor Fisher's calculation are, it is to be feared, in excess of the prices realisable in the interior parts of the country, where high railway traffic rates, and haulage have to be deducted. It is doubtful if higher figures may be reckoned upon, in places distant from shipping ports, than those supplied to the writer by Mr. Fitzsimon, timber merchant, Dublin, as ruling in the central parts of Ireland, for clean, workable timber, viz. :—Spruce, 3*d.* per cubic foot; Larch, 4*d.*; Beech, 4*d.*; Elm, 6*d.*; Ash, 12*d.*; Oak, 18*d.* There is no doubt, however, that were it possible to establish local wood-industries—the case which Prof. Fisher supposes—large profits might be realized.

"If there is a demand for larger timber, the forty years old Scotch pines may be thinned and underplanted with Weymouth pine, which will grow up under their shade, and the whole wood kept up with the necessary thinnings till the age of eighty years, with better financial results than those given above. When the older wood is mature, the Weymouth pine may be cut out, and the Scotch pine regenerated naturally, so that the expenditure on planting could be saved.

"This is an instance of how inferior soil quite unsuitable for agriculture may be utilized; but better returns will be obtained should the soil be good enough to grow larch, Douglas fir, silver fir, or Spanish chestnut, all of which species flourish in Ireland. Larchwoods forty-five years old, in Pembrokeshire, were sold in 1895 for £70 an acre, and some Irish larchwoods sixty-four years old in 1894 produced £127 an acre; but in neither of these cases is the value of the previous thinnings given. Spruce might also be grown for paper-pulp; but this species generally produces a spongy wood in our climate, being too soft for ordinary building material, though it may be improved in quality by keeping the woods dense."

On page 100 the same author supplies other information which is calculated to be of special interest in Ireland; he writes thus:—

Trees for Peaty Lands.

"The following trees are chiefly recommended for peaty lands:—Scotch pine, alder, birch; Austrian and mountain pines do well, but yield inferior wood; Corsican pine is better. There is a difference of opinion about larch, which does not generally thrive in bog-land; but if the land is treated as already advised, larch will prove successful.

"In order specially to study the nature of plantations on bog-land, Dr. Schlich visited some bogs near Bremen and Hamburg, where extensive plantations have been made, and has published some valuable notes on the subject in his report of October, 1895, on the Knockbog plantation. He considers that on old drained and manured bog-lands, irrespective of their depth, profitable forestry can be carried on; on newly-drained bog-lands profitable forestry ceases with a depth of bog of about 3 feet, unless such land is manured and improved by bringing mineral soil on to it. Birch does best on the deeper bogs, and splendid oaks grow where the bog is less than 2 feet deep, and fairly good oaks on bog not more than 3 feet deep. Weymouth pine appears to do well on these German bogs, then Scotch pine and spruce; but there is little larch.

In any scheme for planting cut-out bogs in Ireland, it must not be forgotten that where turf fuel is required the permanent maintenance of the bog should be secured. I have dealt with this question in Vol. V. of the 'Manual of Forestry.'

The Pine Weevil.

"Valuable information is supplied in the reports of the Irish landowners regarding the effects of re-planting with the same species, after larch, Scotch pine, or spruce have been felled, and the Marquis of Waterford recommends waiting one or two years after larch, and four or five years after Scotch pine or spruce, before re-planting the area. At Curraghmore, on high dry land, the pine weevil destroyed nearly all the larch and Scotch pines planted and re-planted in three successive years, after a crop of Scotch pine had been felled. The ground was then left fallow for four years, and when again planted produced a most flourishing crop of trees. Fallow may not, however, be necessary on very good soil, and may be avoided by extracting the old stumps in which the beetles breed."

Expenses and Profits.

As regards the important questions of expense and profit, we read on page 101:—

> "Dr. Schlich estimates the cost of draining and fencing at £2 an acre, and of planting, including plants at £2, the amount usually spent in Scotland on *notching in* two-year-old plants. Where larger plants are used, and pitting adopted, planting and plants should cost about £4, and the total cost, including draining and fencing, would not exceed £6 an acre.
>
> "It is stated that in drained bog it is best to put in a shovelful of gravel before planting. . . . Eight feet is too far apart, 3½ or 4 feet being better, the former for Scotch pine, which forms big lower branches. A common mistake in Ireland is to plant too far apart, and not to give sufficient depth to plantations which, where skimpy, are useless.
>
> "There is a general concensus of opinion in favour of larch and ash as the most profitable timbers to grow. Ten years old larch poles from thinnings sell at 1*s*. and 1*s*. 6*d*. a dozen, and older larch poles at £5 per 100 and up to £40 an acre. The best report of sales of larch I have hitherto heard of has been very kindly placed at my disposal by Colonel Bayley, of Killarney Hall, Bray. The trees were growing on land of

good quality, but too steep for any purpose but planting; the heavy timber of 9 inches diameter at the small end, and over, was sent to Liverpool, the tops were sawn into pit sleepers, and altogether 138 tons were sold, the cost of marketing being 10*s*. a ton, including all costs. The price realised was, after deduction of 10*s*. per ton expenses, £125, while there remained on the area 70 larch and oak and ash, worth £50, and £15 realised as value of tops; total value of 1½ acres of timber, 64 years old, £190, or £127 per acre.

"At Powerscourt larch plantations thirty-five years old, where the trees are 1½ feet in girth and 50 feet high, can be sold as they stand for £50 an acre, a soil rental of 13*s*. an acre, while after conversion of timber at the sawmills on the property, the price is trebled per cubic foot, the increased cost being not more than the original value of the wood as sold standing.

"Ash thirty years old and upwards sells at 1*s*. a cubic foot; it is used for wheelwrights' work, staves for butter-tubs, and boards for general purposes. Alder sells readily for flax-spinners' rollers, and as well as birch, for clogs, and all hard-woods sell well when there is a bobbin factory near. Elm is in demand for wheelwrights' work and coffin-boards, and sycamore for mangles, rollers, &c. Large oaks sell at 2*s*. 6*d*. a cubic foot, but are unfortunately rare; whilst oaks for weir-poles, 23 feet long, sell at Limerick at 20*s*. a dozen. Beech sells at Limerick at 15*s*. a ton for butter-firkins, but is chiefly used for fuel. At Dromore, Co. Kerry, the value of fifty years' old mixed plantation is put at £80 per acre."

The author also says, on pp. 93, 94:—

"In the management of coppice—with standards, it is essential that the underwood should be of a class to command a ready sale; . . . and ash underwood has been recently sold in Somersetshire for £12 an acre. The standards should be chiefly oak, and the rotation of the underwood not less than twelve years. It should be remembered that the longer the rotation of the underwood, up to thirty years, the more the soil is enriched by dead leaves, the greater the value of the underwood, and the cleaner and longer the poles of the standards. In the vicinity of coal mines, where the underwood serves for pit props, the rotation should not be less than twenty-five years.

"As regards the standards which are felled immediately after the underwood, there should be a regular succession of ages on the ground, and, say, twenty saplings planted for every mature oak felled. Supposing the rotation of the underwood to be twenty-five years, there should be, per acre, on a felling area:—

60 sapling oaks, ...	5 years old.
30 oaks, ...	30 ,,
20 ,, ...	55 ,,
5. ,, ...	80 ,,
1 ,, ...	105 ,,

"As soon as the underwood has been removed, all defective standards and those overcrowding one another should be felled, and we might thus fell:—

	£
1 oak, 105 years old, worth	16
2 ,, 80 ,, ,, . . .	20
5 ,, 55 ,, ,, . . .	10
5 ,, 30 ,, ,, . . .	2
13 oaks, worth	£48

"Then adding £12 as the value of the underwood, we have £60, the value of one acre of felling every twenty-five years, which, allowing £2 for the cost of planting sixty sapling oaks, and filling up gaps in the underwood, gives £2 6*s*. 8*d*. per acre, as the annual yield of the wood without deducting rent, rates, taxes, and supervision, supposing it to consist of 25 acres, on one of which fellings are effected annually."

CHAPTER XIII.—WATER SUPPLY.

Drainage Areas and Watersheds.

In the previous chapter drainage areas and river basins were mentioned in connection with the distribution of the fertilising materials, taken up by flowing water from the geological Formations. They will here be described as an important feature of the comprehensive question of water-supply. Lines may be laid down on any map giving the rivers, so as to separate the head waters of adjoining drainage systems as previously described. These watershed lines fairly correspond with the medial lines of mountain ranges; the lines in such case connect the culminating points of the high grounds.

On a small-scale map little more can be shown than rivers and larger tributaries. On the map accompanying this volume the head waters of the tributaries are more exactly represented, and the watersheds would consequently possess greater curvature. And if a portion of Ireland were selected and represented on a scale of one mile to an inch instead of ten miles to the inch, as in the case of the present map, the watershed between two tributaries, or branches of tributaries, could be traced with proportionate accuracy, and would be found to follow a tortuous course, especially if the portion of the country selected were fairly level.

Water Supplies for Towns.

In fixing upon collecting areas for town supplies, those are selected where the water is free from contamination with organic matter, especially albuminoids and ammonia; and from poisonous metals, barium, zinc, manganese, and chromium. Good drinking water should not contain more than 1-10th grain of lead or of copper per gallon. The scarcity of minerals in Ireland renders the chance of danger, on account of deleterious metallic contents, very slight. The chief sources of pollution are drainage waters from tillage land. As small a quantity as ·1 part per million of albuminoid ammonia, renders water very doubtful in quality, and that containing ·15 per million is unfit for use.* Cultivated tracts should therefore be avoided; and of harmless compounds—lime, magnesia, potash, iron, chlorine, silica, carbonic, and sulphuric acids, &c.—water should not contain more than 40 grains per gallon or 57·14 parts per 100,000.†

---

* Water Analysis, by Frankland, pp. 43, 124.

† The Thames Water-supply contains 18·5 grains per gallon; New River, 17·6; Manchester supply, 4·7; Glasgow (Lough Katrine) 2·3; the Atlantic, 26·88 per gallon. The Thames at London Bridge contains 1·02 parts of free ammonia, and ·59 of albuminoid ammonia per million.

Though the lack of lime in water is a disadvantage to health, and seems to be a cause of decay in teeth, yet for general use soft water is found more serviceable than hard, which usually contains a relatively large proportion of lime, either as carbonate or sulphate. This point will be referred to in connection with springs, at present we are concerned with surface water; and in order to secure the desired kind for large supplies, the collecting areas are chosen amongst hills, where little if any tillage is practised, and where, moreover, reservoirs are easily made, by forming poundage embankments at convenient points across valleys.

Dublin and Belfast Supplies.

For the Dublin water-supply, the Vartry River is thus dammed at Roundwood, and the water drawn from an area of Silurian grit and slate. Belfast supplies are taken from off basalt at Stonyford and Carrickfergus. These are practically non-calcareous rocks, and the water consequently does not show an objectionable degree of hardness. The accompanying analyses* represent the quantity and nature of the solid matters in solution.

THE VARTRY PIPE WATER, DUBLIN.

The Composition of the Vartry Pipe Water, taken from a tap in the City Laboratory, 17, Castle-street, was as follows (analyses by Sir Charles Cameron). One Imperial Gallon (70,000 grains) contained :—

	SAMPLE TAKEN.		
—	1st October.	1st November.	2nd December.
Total Solid Matter, Including—	4·200	4·200	4·200
Albuminoid Ammonia,	0·0085	0·009	0·007
Saline Ammonia,	0·0025	0·002	0·001
Nitrous Acid,	None.	None.	None.
Nitric Acid,	Trace.	Trace.	Trace.
Chlorine,	0·894	0·894	0·894
Equal to Chloride of Sodium,	1·474	1·474	1·474
Oxygen absorbed from Permanganate of Potassium Solution—			
After 15 minutes at 80° F.,	0·077	0·086	0·085
After 4 hours do.,	0·142	0·155	0·140
Hardness before being boiled,	1·7°	1·7°	1·7°
Hardness after being boiled,	1·6°	1·6°	1·6°
Microscopical Examination,	Satisfactory.	Satisfactory.	Satisfactory.
Colour looked at through a tube 2 feet in length.	Slight Yellow.	Light Yellow.	Light Yellow.
Suspended Particles,	Few.	Few.	Few.
Sediment,	Slight.	Very slight.	Very slight.

---

* Kindly supplied to the writer by the City Engineer of Dublin. Mr. Spencer Harty, and by the Secretary of Belfast Waterworks.

The water of the Grand Canal, which is used to some extent by the Rathmines Township, gave the following results in respect to hardness, upon analysis by Professor W. Noel Hartley, F.R.S.*

—	May.	June.	July.	Aug.	Oct.	Nov.	Dec.
Total Hardness (Degrees),	10·6	17·5	14·06	15·16	20·56	19·13	22·86
Temporary Hardness (do.),	6·4	12·1	9·49	10·30	15·27	14·13	16·29
Permanent Hardness (do.)	4·2	5·4	4·57	4·86	5·29	5·00	6·57

Analyses of Belfast Water Supplies (by Dr. Percy F. Frankland, F.R.S.)

(Per Gallon.)	Woodburn, Carrickfergus District.	Stonyford.
Total Solid Matter,	17·72	13·36
Organic Carbon,	·240	·420
Organic Nitrogen,	·032	·043
Ammonia,	Trace.	Trace.
Nitrogen as Nitrates and Nitritis,	·026	·031
Total Combined Nitrogen,	·058	·074
Hardness, temporary,	·0	·0
Do., permanent,	8·9	6·4
Do., Total,	8·9	6·4

An additional supply is now being introduced into Belfast from the granite area of the Mourne Mountains, where the waters of the Annalong and Kilkeel Rivers are impounded for the purpose.

The analyses of the water from these rivers, as given by Professor James Dewar, F.R.S., are as follows—omitting such notes as are irrelevant to the present purpose.

—	Annalong River.	Kilkeel River.
Nitrogen as Ammonia,	·001	·001
Colour of residue,	Pale Yellow.	Pale Yellow.
Total Solids,	2·80	2·20
Chlorine,	1·080	·936
Equals Common Salt,	1·770	1·534
Organic Carbon,	·058	·050
Do. Nitrogen,	·018	·017
Hardness before (boiling),	1·640	1·370
Do. after,	1·60	1·20

---

* To whom the writer is indebted for permission to reproduce these figures, Prof. Hartley's analyses are complete and detailed, but it has been thought unnecessary to reproduce them in full here.

(All the results are expressed in grains per *gallon*, except in the case of hardness, and the last two analyses, which refer to 100,000 parts).

It is interesting to note, concerning the above water samples, how small the degree of hardness is, as compared with that of water flowing off the basalt, given in the preceding analyses.

Quantity Required.

The allowance of water per head of population is usually something over 30 gallons daily; 33 gallons in London; 31 in Paris; 35 in Belfast, and so forth. The Vartry supply is ample for Dublin, and the "extra municipal" demands—containing an inclusive population of 350,000. The population and the daily rate giving the requirements of each case, provision is made accordingly. The collecting region being fixed upon, calculation of the amount available is based upon two factors, viz., the rainfall usual to the area, and the drainage area included between the watershed which surrounds the valley, and the line of intercepting embankment thrown across the valley to form the poundage reservoir. The position of the embankment must leave sufficient collecting area above, and must otherwise be decided by circumstances offering facility of construction.

It has been shown that the proportion of rain water which finds its way into discharging sewers in the case of land covered with vegetation is between one-third and one-fifth of the total quantity that falls. On clay, less than one-half, and on gravel and rubble about four-fifths. For the sake of rough calculation we may take it to be one-third for all.*

Allowance for Contingencies.

Evaporation carries off a large proportion of rain water; and this source of loss in a time of continued drought is liable, even with the fullest provision, to bring about a serious dearth of water. To meet such a contingency a much larger area must be taken in than would be necessary on the basis of an *average* weekly or monthly rainfall. The conditions find illustration in the case of the Thames basin, which is as follows, viz.:—After a dry period the daily discharge at

---

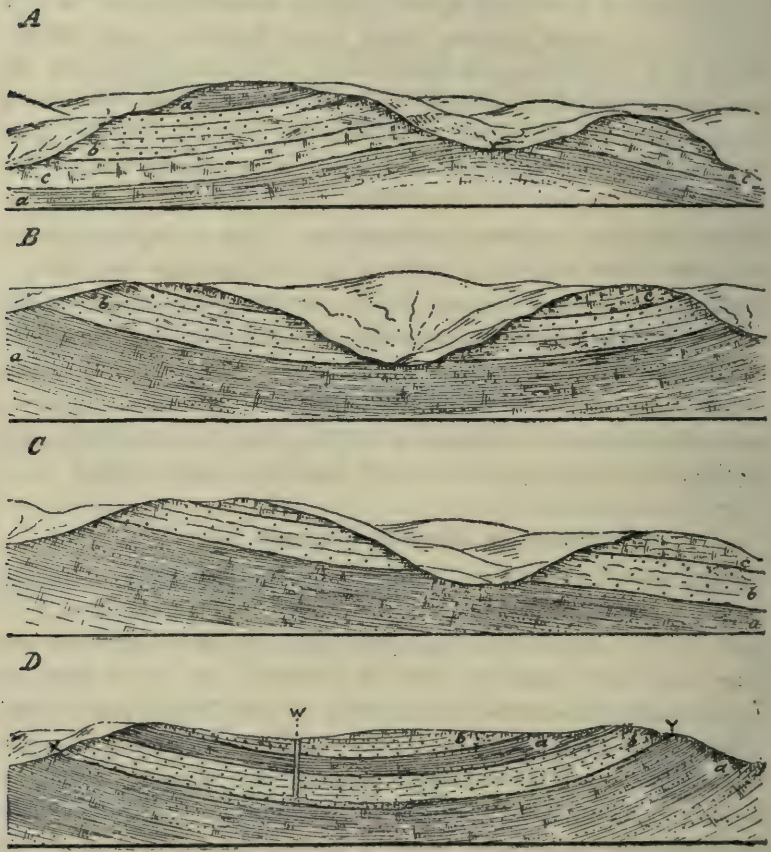
* Harrison, from eleven years' observation, gave 1,353 million gallons daily, discharge for the Thames above Kingston; Beardmore 1,145 million gallons daily, from 18 years' observation. Prestwich adopted the mean of 1,250 million gallons daily which was a discharge equivalent to 8 inches of rain for the total drainage area of 3,675 square miles. The rainfall for the area was 27 inches, so that the discharge was found to be a trifle under one-third of the rainfall.—Anniversary Address to the Geological Society, by Sir Joseph Prestwich, F.R.S. Jour. Geo Society, Vol. 18, 1872.

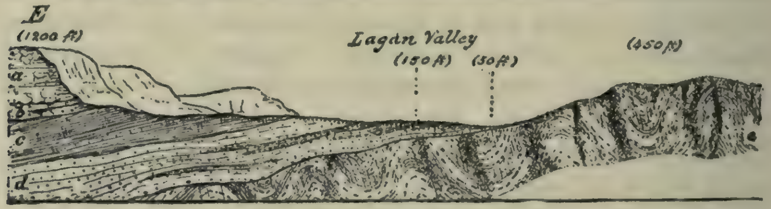
Kingston was only 350 million gallons, instead of the average daily discharge of 1,250 million gallons. This discharge was sustained by springs issuing from 2,442 square miles of permeable strata, or two-thirds of the entire drainage basin above Kingston; and did the entire area of 3,675 square miles consist of impermeable strata, the continued supply from springs would have been trifling. Returning to conditions of the Irish town-supplies, the hilly regions more frequently consist of impermeable than of permeable strata; and here in consequence the rain water would quickly disappear by direct discharge, or through evaporation. This is the case around the head waters of the Vartry River, so that some years ago Dublin was threatened with a water famine, and the collecting area has recently had to be much increased. Basalt, granite, metamorphic schists, fine grit, slate, shale, and marl are all comparatively impermeable rocks; as is also Limestone, though joints are so common, and liable to become enlarged by solution, that it is practically permeable. Sandstone presents many degrees of permeability.

Permeable Strata in Drainage Areas.

Rain water, percolating through soils and sub-soils, or falling upon bare rock, penetrates into and passes through sandstone; or finds its way downward through joints and fissures in limestone. In either case, most commonly that of sandstone, the strata may lie between impervious beds—those of clay or shale, which prevent the water passing through. In the case of limestone, rain water, charged with carbonic acid from the atmosphere, eats it away, enlarging the fissures along which it trickles and flows. To this cause is due the existence of "swallow holes" and underground channels so frequently to be met with in limestone districts. One of the most remarkable and, perhaps, best-known examples of underground water-flows, is that which discharges the drainage of Lough Mask catchment basin—about 360 square miles—into Lough Corrib. These lakes are separated by a neck of land some three miles wide, across which no visible channel exists, except an artificial canal, which was excavated at great cost, with the intention of forming navigable communication between the lakes. The canal has proved an utter failure, because of the honeycombed condition of the limestone in the vicinity of Cong. At this place, and in its neighbourhood, the underground water may be observed through natural openings and in gloomy caverns, with which superstitious awe has not failed to connect some dramatic episodes, recounted in the legendary lore of the locality.

Having regard to the circumstances just mentioned, it will be perceived that the occurrence of permeable strata within a drainage basin variously affects the available supplies; the manner in which this happens may be shown by a few illustrative sections.





A to *E* (Figures 51 to 54.) Diagrammatic sections illustrating relations between pervious and impervious strata. *a*, shale; *b*, sandstone; *c*, limestone; X and Y positions where springs would make their appearance; W, well or boring, in which water would rise to or near the surface.

E (Fig. 55.) Section across the Lagan Valley; *a*, basalt forming the escarpment south west of Belfast; *b*, Chalk (white limestone), and Greensand; *c*, New Red Marl; *d*, New Red Sandstone; *e*, Silurian slate and grit beds contorted, overfolded, crushed and dislocated.

A. If the permeable strata dip away from the valley centre, the portion of the rainfall which sinks into the earth is liable to be carried away into the adjoining valleys.

B. This case presents the contrary conditions, viz., those in which water percolating through the porous strata finds its way from adjoining grounds into the valley in question, so that the supply may be much larger than the area within the watershed would entitle us to expect.

C. Represents conditions in which some water is contributed from outside, and some lost to the valley.

D. If a stratum or series of beds of sandstone occur between impermeable strata, shale, or marl, above and below, the water which percolates into the sandstone at its outcrops (X and Y) collects in the saucer-shaped tract until it issues in springs along its margin. Such springs are good indications of the positions of boundary lines, and are used in this way in geological mapping, as along the escarpments, say, of the sandstone and limestone hills in Fermanagh and Cavan.

Artesian Wells.

If the sandstone, as shown in the figure D, be tapped by a boring made at W, the water rises to the same level as that at which it stands in the stratum; and if the ground where the boring is made should be at a lower level than the outcrops (X and Y), the phenomenon known as an " Artesian Well " would be exhibited, in the water rushing up as from a fountain.

Springs.

The necessity of obtaining good potable water, in and near towns and farmsteads, renders the subject of springs one of the most important with which geology deals. A good well should afford a sufficiency of pure, clear water; should be located out of reach of polluted surface water, and staunchly walled in, in its uppermost 10 or 15 feet, to guard against its being infested with vermin. Water from 50 to 60 feet deep will be " cool " in summer and " warm " in winter, because, coming from the vicinity of the " invariable stratum," it is not affected by the summer heat and winter cold; and by contrast it gives the illusive impression commonly experienced.

The conditions presented in the figures given above, and generally such as those prevailing in the Thames basin, where alternating permeable and impermeable strata occur, are somewhat easily discerned. Springs occur along certain lines, and more or less water may be counted upon in wells sunk through porous strata. Circumstances sometimes occur, however, in which experts in well-sinking are outwitted, and in which geologists with difficulty account for the phenomena encountered. Instances have been met with in which "dowsing" has succeeded where other less occult and more "scientific" means of water-finding had failed.*

A Specific Case.

In ordinary cases, however, geology will be accredited with affording genuine assistance. An instance in which the writer was recently concerned will serve for illustration. A landowner required, for the supply of his house and yards, 10,000 gallons daily. A small plateau was chosen as the site of a well, at some distance from the house, and about on a level with its roof; upon the plateau a reservoir was to be formed to contain the water pumped; and the well was sunk fifty feet, and bored twenty feet deeper. The supply obtained amounted to only 2,000 gallons daily; and the question to be decided was whether, by boring further, the required amount of 10,000 gallons daily could be obtained. There are several springs in the vicinity, in the low ground, but none of great volume. It is probable that a well sunk to the extent above mentioned, in the *low* ground, would secure a much larger supply than the 2,000 gallons; but the convenience of the position, in the first instance, decided as to the site. The owner hoped that the red sandstone of the Lagan Valley, not far distant, which occurs at a much lower actual present level than the site, would be pierced, and thus a large supply of water secured if the boring were continued; but the sandstone is of Triassic age, while the slate and grit are of Silurian age, and consequently pass under the former; so that the hoped for source of water could not be reached by boring further. A section across the Lagan Valley (Fig. 55, p. 180) renders this manifest.

Wells in New Red Sandstone.

The New Red Sandstone is a reliable source of good spring water, and several wells have been sunk in it for private supplies at Belfast. Two of these are at Ross's Aerated Water factory; and the descriptions of these wells as well as analysis of the water from one, kindly supplied to the writer by the company, are here given. They will serve for illustration of the kinds of strata met with, and the supplies afforded by the New Red Sandstone of the Belfast region:—

"The old well is 226 feet deep, supplying 1,200 gallons per hour, used only for washing purposes. It was sunk through rubble (5 feet), silt, marsh, peat (21 feet), old river bed (7 feet), stiff red clay (37 feet), gravel (8 feet)—all probably superficial deposits; next followed, red freestone (146 feet) and "fine gravel" (2 feet).

---

* The reader who wishes to follow up this subject might consult two interesting volumes compiled by Professor Barrett, F.R.S., in which are given accurate and exhaustive records of the "Water-finders'" successes and failures—with about 75 per cent. to his credit.—"Proceedings of the Society of Psychical Research" on the so-called Divining Rod, by W. P. Barrett, F.R.S., &c.

"The new well was made in 1899, 420 feet deep, 4 inches diameter-bore, supplying 9,000 gallons daily, and capable of supplying more if necessary.

"The analysis of this water, which is that used for Messrs. Ross & Sons' cordials gave the following results :—

Total Solid, ...	18·5000	Parts per 100,000.
Saline Ammonia, ...	·0048	
Organic Ammonia, ...	·0039	
Oxygen absorbed, ...	·0790	
Chlorine, ...	4·5	
Equivalent to common salt, . .	7·4	
Nitrogen as Nitrates and Nitrites, .	·32	

Poisonous metals absent.

Water "keeps" very well.

"The mineral matter in the water consists chiefly of sodium chloride, calcium chloride, and sulphate. The organic matter is insignificant." The statement appears over the signature—

"S. Templeton."

Flow of Water in Sandstone.

The conditions which regulate the quantity of water entering wells sunk in sandstone, are the pressure (due to gravity and acting in opposition to capillary attraction) under which the water moves, the length of the course it has to take, the sizes of the sand grains, the porosity of the sandstone, and the temperature of the water. The velocity of flow is in direct proportion to the pressure, and inversely proportionate to the length of the course. This is known as "D'Arcy's Law."

If V be the velocity,
P the pressure,
L the distance through which the water flows; and
K a constant dependent upon the size of the sand grains, the amount of interstitial space, and the viscosity of the water, which, however, itself varies with the temperature, then

$$V = K\frac{P}{L}$$

Gravelly layers in sandstone not only are likely to contain more water than the finer-grained rock; but, as is obvious from D'Arcy's law, the supply contained in coarse strata discharges more quickly into wells. There is consequently a double object gained in tapping gravelly layers.

Other Water Analyses.

Some analyses of waters issuing from Carboniferous shale and shaley limestone are here given. They will be seen to stand in marked contrast to those of the Belfast New Red Sandstone springs as above, and to contain substances which render the waters medicinal. The first three are analyses of Lisdoonvarna springs; the fourth is that of Lucan Spa, where the water issues from the "Calp" or shaley limestone. The oxidation of iron pyrites and organic matter in contact, produces sulphuretted hydrogen which exists in the water, but in the analyses was not determined. Prof. J. Emerson Reynolds, M.D., F.R.S., gives 8·17 cubic centimetres of this gas per litre, and 41·06 c.c. of carbonic acid gas, as the results of two analyses of the Lucan water.

Analyses of Waters at Lisdoonvarna and Lucan.*

Contents.	Rathbane.	Magnesium.	Double Arch Bridge.	Lucan Sulphur Spa.
Sodium Carbonate . . .	—	—	—	28 000
" Sulphydrate . .	—	—	—	0·501
" Chloride . . .	4·195	4·136	3·913	3·208
Lithium Chloride . . .	—	—	—	0·006
Potassium " . . .	—	—	—	2·250
" Sulphate . . .	·555	·409	1·027	1·230
Calcium " . . .	6·173	5·209	3·286	3·402
" Carbonate . . .	9·600	19·590	4·009	1·302
Magnesium " . . .	·495	·675	·345	3·601
" Sulphate . . .	2·604	4·926	5·481	—
Iron Carbonate . . .	3·132	1·870	2·291	—
Alumina	·140	·220	·120	and iron ·800
Silica	1·120	1·330	·840	—
Organic Matter . . .	1·100	·944	·570	Organic Nitrogen } trace
Total ingredients in the Imperial gallon, in grains.	29·114	39·309	21·882	44·300

Rise and Fall in Springs.

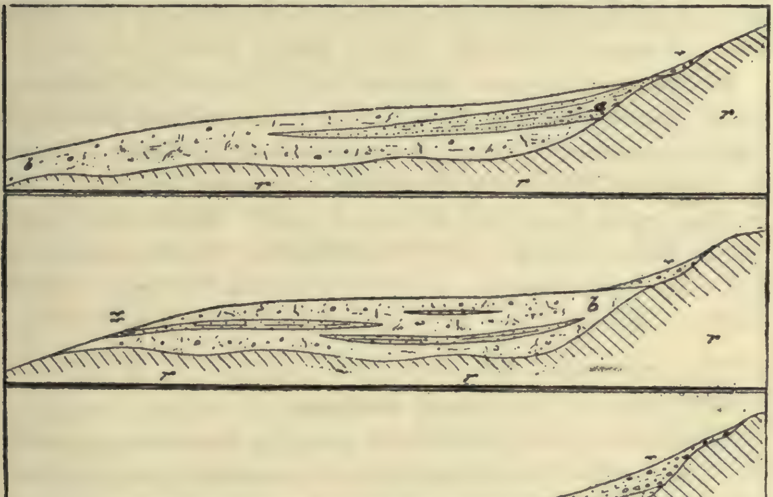
Daily and even hourly fluctuations in the level of water in wells, and in the discharge from tillage drains, are caused by changes in the pressure of the atmosphere, as indicated by the barometer; and by changes of temperatures as already noted. Not only is the viscosity of water increased by heat, but the pressure of air in the soil, which bears a relation to that of the atmosphere, and is increased with the increase of temperature, affects the rate of flow and discharge in a very remarkable way. Professor King, of Wisconsin, gives some interesting diagrams setting forth these effects.*

---

* For which the writer is indebted to Professor Tichborne of Dublin. Prof. Reynolds' figures are given in Proc. Roy. Dublin Soc. (N.S.), 1881-1883, pp. 259, 266.

Springs in Drift Deposits.

In Drift-covered ground, boulder-clays are usually impervious; some, consisting chiefly of marl, are practically so, but such clays, especially in the vicinity of hilly ground, often contain beds of sand and gravel, which are good reservoirs for small water-supplies. On sloping ground the gravelly beds may be continuous with rubbly covering of underlying rock, in which case, represented in the accompanying plate, diagram Fig. 56, the water descending the slope after rain quickly charges the gravel beds. In other cases the



Figures 56 to 59.—commencing at top, diagrammatic sections showing relations of sands, boulder-clay, talus and underlying rock: *a*, sand and gravel, usually stratified, sometimes occurring as layers in boulder-clay as in Fig. 57; *b* boulder-clay comparatively impervious; *r*, rock; ⌒, talus; ≈, position where springs would appear.

---

* "Text-book of Agricultural Physics," 2nd ed. p. 270 *et seq.*

layers of sand and gravel may be non-continuous; they then receive the water which slowly percolates through the upper less pervious layers, and though it may afford supplies according to their capacity, they do not quickly fill. This case is shown in section (Fig. 57). Water collecting in such layers may discharge upon a slope, as at ♒ in the diagram, or may require to be tapped by a boring, as an actual instance which the writer was asked to see in the county of Wicklow.* A third case illustrated in Fig. 58 is one actually met with on the opposite side of Carrigoona Hill to the one last referred to. A boring was made near the base of the hill, and it proved futile, though the ground showed signs of a water supply close to the surface. The water descending the hill side seems to have percolated through the talus or rain-wash and escaped over the surface of the clay without sinking further.

An important hygienic condition may here also be mentioned. If, as illustrated in Fig. 59, sand and gravel soil and subsoil rest upon a retentive clay, beneath a farmyard or homestead, it is well to determine the direction of the slope of the clay, by three or four borings, before fixing upon the site of a well. Should this be sunk on the surface up-slope side of the homestead, the water cannot be free from contamination. If below it, there may be a deficient supply. The site should be chosen at a distance on either side.

Water Hardness.

"Hardness" is imparted to the water by the calcareous matter over which it flows, or through which it percolates; springs in limestone are therefore hard, and some issuing from limestone gravel, and boulder-clays possess a "total" degree of hardness higher sometimes than 26.

Reference was made to this property in a previous chapter (p. 78). It may now further be explained that degrees of hardness are estimated upon the basis of one grain of carbonate of lime in each gallon of water, or the amount of sulphate of lime or other substance capable of producing an equal deadening effect upon soap solution. Water containing 13 grains of carbonate of lime, or its equivalent, in each gallon of water, has 13 degrees of hardness, net. or 14 degrees of total hardness, because water of 13 degrees hardness requires a slight additional quantity of soap solution to produce a positive lather which *will last* for about five minutes—an essential point in making estimations.

---

* By Professor Barrett, who through the direction of Mr. Stone, a "water-finder," secured a supply in Drift resting in a hollow, on the side of Carrigoona Hill, for his house built there in 1901.

Now, if Castile soap, representing 60 per cent. of olive oil, be taken to form the test solution, one gallon of 16 degrees total hardness will be found to require 160 grains of such soap; and thus about 1 lb. of soap will be used up in producing lather in forty-four gallons of water of the degree of hardness named.* A quantity very slightly less than this may be considered wasted.

Water-power.

It may be desirable to ascertain the power available in a certain water supply, to be utilised by water-wheel or turbine; and the following figures are given as illustrative of the point. The "power" depends upon several factors, which may be summed up in two, viz., *quantity* and *fall.* The quantity is determined by the width and depth of the channel, and the rate of flow. Channels conducting the water are usually rectangular, then:—

If d = depth of channel in feet,
w = width " " " "
v = rate of flow per minute in feet (average),
h = fall in feet,

$$\text{Power (foot-pounds per minute)} = d \times w \times v \times 62\tfrac{1}{2} \times h,$$

$$\frac{d \times w \times v \times 62\frac{1}{2} \times h}{33000} = \text{Horse-power.}$$

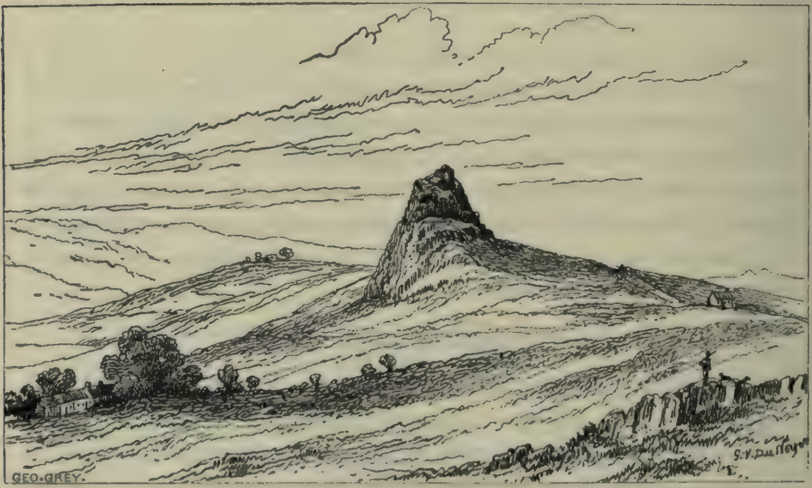
Take as an example a wooden channel 3 feet wide, carrying a stream 9 inches deep, at an average rate of 2 feet per second (120 feet per minute) and a fall of 20 feet, the calculation is made by multiplying the factors, 3, $\frac{3}{4}$, 120, $62\frac{1}{2}$ and 20, and dividing by 33,000. The total horse-power is found to be $10\frac{1}{4}$. A much smaller stream with good fall—conditions which are by no means uncommon in Ireland—might be utilised for many purposes, by persons engaged in agriculture.

Utilization of Water-power.

The hopeless abandonment of milling in the country parts, and the use of steam, wherever the cheering rumble of machinery is to be heard, have tended to render Irishmen insensible to the enormous waste of power every day proceeding at their very doors. If the community could become impressed with a sense of this waste, those possessed of a little capital might find a profitable channel of outlay, as an adjunct to farming, now that machinery is adapted to almost every conceivable enterprise. This would apply especially in the winter season, when water is abundant, and occupation for labourers slack. An obvious purpose to which water-power might with economy be applied is that of dairying operations in the case of private as well as public creameries. It could also be applied to stone-breaking, instead of more costly steam power. Trituration of rock may be performed by means of "stamps" worked by water-power; and if limestone were thus treated, particularly varieties found to be rich in phosphates, a profitable industry might be formed. The comminuted rock would be almost as effective as gas-lime for top-dressing; and its use would reinstate a valuable fertiliser, which has fallen practically into disuse, through the prohibitive cost of lime, because of the present high price of fuel. The trituration and use of basalt even, or other basic igneous rock, have been proposed, because of the richness in phosphates of some varieties of such rock species. The suggestions here offered rest upon by no means a visionary basis. In the neighbourhood of Rothamsted, the writer not long since witnessed the top-dressing of clay soil with broken up chalk, taken from beneath the retentive subsoils. In a finely-powdered condition, limestone rock, having the same composition as chalk, would be equally effective as a fertilizer.

---

* 7,000 grains ÷ 160 = 44 nearly.



View of Sugarloaf Rock, S. of Waterford, looking westward, visible from many parts of the Counties of Wexford and Kilkenny.*

---

* From Explanation of Sheets 167, 168, page 33.

CHAPTER XIV.—Recent Life Forms.

What has come before the reader in the preceding chapters will prepare him for a discussion of the stocking of the island with some of its numerous forms of animal and vegetable life. Though many of them, chiefly those known in domestic and agricultural spheres, have obviously been imported, there is practical agreement amongst all, that many are of automatic migratory origin; and many show the results of development through special care and protection, and crossing, whether natural or by human intervention. Some of the present forms are traceable backward to a remote past; others once present here have become extinct.

Animal Remains in Peat.

Large quantities of animal remains have been disentombed from the peat deposits throughout Ireland, often in a comparatively good state of preservation. In some cases bones are found much decomposed, the remains containing phosphate of iron (*Vivianite*) and salts of lime. Among the remains have been identified those of three species of deer*—the Red Deer (*Cervus elaphus*), still living in Ireland; the Reindeer (*Tarandus rangifer*), which now finds its congenial habitat in the frozen regions of Northern Europe; and the great Irish Deer (*Cervus giganteus*, erroneously called Elk—*C. megaceros*, or *Megaceros Hibernicus*). The remains of this last noble animal are of special interest, occurring, as they do, in much larger quantities in this country than in England or on the Continent. They are mostly to be found in the clays and marls which underlie the peat, and have a wide distribution throughout the country. One hundred heads of Megaceros were found in the clays which underlie Ballybetagh Bog, near the Three-Rock Mountain, in Dublin.†

Human remains have also been found entombed in the peat, together with numerous articles of handicraft, &c.—canoes, weapons, implements, utensils, wearing apparel, crannoges or pile-dwellings, and vessels containing a fatty substance known as "bog-butter," which also occurs in unprotected lumps, in good state of preservation. An exhaustive and interesting list of such discoveries, up to 1863, was compiled by the late Sir W. R. Wilde, and communicated to the Royal Irish Academy. It appears in the publication of the Society under the title "Descriptive Catalogue of Irish Antiquities."

---

* "Physical Geology of Ireland," E. Hull, 2nd ed., pp. 302, *et seq.*

† "Great Ice Age," 3rd Ed., p. 417.

Cave Deposits.

Deposits found in the caves of Fermanagh, Waterford, Clare, and other limestone regions have yielded remains of extinct animals, amongst which are those of the mammoth (*Elephas primigenius*); of hippopotamus (though this is doubtful); of the other extinct animals previously mentioned; and two or three species of bears (*Ursus arctos? U. spelæ, U. ferox*), the wolf and the wild boar. The bones of these prehistoric animals were accompanied by those of others not yet extinct, viz., rabbit, otter, marten, badger, hog, sheep, goat, horse, ox, seal.* The remains of man were discovered in some cases with those of the extinct animals; and his primitive existence in Ireland was marked by the use of flint implements which have been met with in many places, especially along the Antrim coast. Other records of the original race are to be observed in cave-dwellings, lake-dwellings, and other primitive abodes; as well as in places of sepulture—barrows, cromlechs, dolmens, and tumuli.

Local Nomenclature.

One of the most interesting monuments of the natural history of the past, is found in the local nomenclature of the country, the names of animals and plants, commonly known, having furnished the roots of names which most places throughout the country still bear. A few illustrative examples are here given.

Horse, Eaċ,	Aughros [Eaċros] horse-peninsula.
,, ,,	Aughinish [Eaċ inis] horse-island.
,, ,,	Cloonagh [Cluain eaċ] horse-meadow.
,, Capal,	Gortnagappul [Gort na g-capal] field of horses.
Mare, Láir,	Cloonlara [Cluain Láir] mare's meadow.
Cow, Bó,	Drumbo [Drom bó] cow's ridge.
,, ,,	Dunbo [Dún bó] fortress of the cow.
Calf, Laoġ,	Clonleigh [Cluain laoġ] calves' meadow.
Ox, Daṁ,	Davenish [Daṁ inis] island of the ox.
,, ,,	Cloonduff [Cluain daṁ] meadow of the ox.
Sheep, Caora,	Ballynageera [Baile na g-caora] town of the sheep.
Goat, Gaḃar,	Glenagower [Gleann na n-gaḃar] glen of the goats.
Pig, Muc,	Tinamuck [Tiġ na muċ] house for pigs.
,, ,,	Muckilty [Muc coillte] pig-woods.
,, ,,	Muckross [Mucros] pig-peninsula.

---

* Lists of animals, including a hippopotamus are given by Prof. Leith Adams, *Proc. Royal Dub. Soc.*, vol. ii., 1880, pp. 45–86; also in the Report of the Committee on the Exploration of the Caves of Kesh, Co. Sligo, *Trans. Roy. Irish Acad.*, vol. xxxii., sec. B, p. 171, *et seq.*

Numerous local names are also derived from original terms for woods, trees, &c., amongst which are those for oak, ash, birch, elm, yew, mountain ash, holly, hazel, alder, apple, elder, blackthorn, white thorn, furze, heath, ivy. It is noticeable that references to fir are not common, from which it would appear that fir, now so common, was originally not in great abundance in the country. The numerous names in which the term *derry* appears, testify to the prevalence of oak woods in Ireland in earliest times.

Spontaneous Migration.

The occurrence of remains of animals and plants, which could not be supposed to have been intentionally imported, leads to an interesting inquiry regarding the conditions under which they could have arrived in the island; for it will be recalled that the existence and character of the Drifts in Ireland necessitated the conclusion, that either the island was almost wholly submerged, or almost wholly covered with ice.

In Chapter XI. the view presented is that held by Sir Archibald Geikie, Professor James Geikie, and other authorities on glacial geology, viz., that the island was swathed in a thick mantle of ice, which rendered life impossible in the country, from Malin Head to Cape Clear, except on the highest mountain crags, these possibly not having been covered with ice or *névé*. In this view, migration, except perhaps in rare instances, must have taken place since the covering disappeared.

Conflicting Opinions.

With regard to this simple and, as appears to the writer, well-sustained hypothesis, geologists are not agreed as to the conditions which prevailed during the age in question, or even as to the immediate cause or causes of the glacial phenomena in Ireland. Some hold that the phenomena are due to astronomical causes, the earth having passed through an exceptionally cold region of space, after a period of warmth in Miocene times, in the northern hemisphere at least; to this, physicists raise the objection that, under conditions of extreme cold, evaporation from the ocean would be trifling, and not sufficient to produce, through condensation of the vapour, great accumulations of snow and ice on neighbouring lands. Others attribute the glacial conditions partly to astronomical and partly to geographical causes, the earth having reached a point in its periodical change of position in the ecliptic, at which it would be furthest from the sun in our winter, instead of being nearest to the sun at that season, as at present; and concurrently with this, a diversion of the waters of the Gulf Stream, which would deprive the northern hemisphere of a large quantity of the heat now carried into it by that ocean-current. Others again suppose the cold during the ice-age to be due to an elevation of northern lands, including the British Islands, bringing much of the present land above the limits of permanent snow. This, in Ireland, would involve an elevation of some 2,000 to 3,000 feet, if the temperature at the ocean level were what it now is; and would produce the necessary conditions for condensation of vapour, as well as for evaporation. Yet, again, others maintain that known zoological and geological facts alike require a recognition that submergence of the present land, to a very considerable extent, must have taken place during the deposition of the boulder-clay. Amongst the authorities who maintain submergence during the ice-age is Professor Bonney, following Lyell; Prof. Cole also favours the view, and Mr. Wright,* of Belfast. The subsidence which would meet the supposed necessities of the case should be to the extent of some 1,500 or 1,600 feet. For such an hypothesis there is no direct evidence.

Opinion of Zoologists.

About the most serious objection to the now generally accepted view of glacial conditions, comes from zoologists, who insist that a thick mantle of ice, covering all but the highest summits, and an extreme climate, are quite incompatible with their facts, viz., that what we may here call the indigenous fauna and flora of Ireland, are characterised by forms which must have migrated hither in earliest Pleistocene times—times, namely, which geologists take as the beginning of their glacial age; and that southern forms are found which could not have survived an extreme northern climate, though mingled indeed with representatives of arctic and alpine fauna and flora. Here, then, scientific authorities, judging the circumstances of the island from different standpoints, appear in hopeless conflict.

Viewing the case more closely, as presented by zoologists, Dr. Scharff and Mr. Carpenter,† of the National Museum, are in agreement with the late Professor Forbes in believing that the earliest of

---

* Mr. Wright, who has given much attention to the Foraminifera, recently informed the writer that he found species of this Order in a sample of boulder-clay taken from the top of Divis Mountain, 1,567 feet above the sea.

† Now Professor G. H. Carpenter, B.SC., of the Royal College of Science.

Miocene or Pliocene migrations brought species from the south-west corner of Europe; and these are denominated Lusitanian, from the ancient name of Portugal.* Dr. Scharff also holds that this fauna was strengthened by an Oriental migration, which came by the Mediterranean basin, and subsequently by Arctic and Alpine migrations; that evidence for a migration from Siberia to Britain is to be observed in the forest bed of eastern England, but that these migrants did not reach Ireland—which inferentially marks the time at which the countries became severed by the present arm of the sea.

A Via Media.

The issues raised are to some extent met by the suggestion of Mr. Kinahan that animals could have crossed the channel on an ice bridge; and by the suggestion of Mr. Lamplugh, to the effect that as in the case of the ice-fields of North-western America, particularly the Malaspina glacier of Alaska, the ice might not only have afforded a bridge, but that the surface was not destitute of so much herbage as would supply sustenance to migrants. The glacier referred to carries an herbage for part of the year at least, and the climate is not inimical to animal life. Professor Cole, in his contribution to "Knowledge" for August, 1902, takes a similar view, and regards the controversy as one which demands the adoption of some such "golden mean." It will be noticed that in these opinions the geographical circumstances of our island are assumed to have been approximately as at present, during and since the ice-age, viz., that there was a channel of separation between Ireland, and Britain and Europe, in part at least filled with ice, with no land connection.

Dr. Scharff's Objections.

Dr. Scharff does not accept the explanation as adequate; and while apparently prepared to admit the possibility of the so-called "Irish Elk," and other mammals crossing in the way suggested, he disbelieves in the ice-bridge as a footing for the extensive migrations of which there are evidences; denies that many species of fauna and flora could have crossed in this way; and points to peculiar localisation of species in Ireland which are not met with, generally, nor in some cases at all, in England. Thus the spotted slug of Kerry (*Geomalacus maculosus*) is confined to South-western Ireland, is not known in England, nor any further north in continental Europe than North-western Spain. A brilliantly coloured woodlouse (*Metoponorthus cingendus*), found in Ireland chiefly on the west coast, is absent from Great Britain, but is known in the south of France. Two earth worms of the Spanish and Mediterranean region, viz., *Allolobophora venata,* and *A. Georgii,* exist in Ireland, but are unknown in England or France. Nor is the evidence derived from existing flora less striking than that afforded by the lowly members of the fauna mentioned by Dr. Scharff. He mentions two plant species, pointed to by Forbes, viz., the arbutus of South-west Ireland (*A. uneda*), which is not indigenous to England, but has a wide range in the Mediterranean region; and the Irish spurge (*Euphorbia hiberna*), which is found only in the South-west of England, besides Ireland and Southern Europe.*

---

* "The History of European Fauna," by R. F. Scharff, B.SC., PH.D., F.Z.S., page 64.

Submerged Area of Propagation.

The association of the fauna and flora of Ireland with those of Spain, Southern France, and the Mediterranean basin generally, is so close that Dr. Scharff considers there must have been an active centre of development somewhere in South-western Europe and North-western Africa, and suggests that the area in question may have comprised land now submerged. The absence from England of the species mentioned, or their scarcity there, is strongly against the supposition that they could have reached Ireland by crossing the Irish Channel from Britain, upon an ice-bridge, even under the most favourable circumstances which the surface of a glacier could present.

Mingling of Northern and Southern Forms.

From the presence of many southern forms in the British Isles, living and extinct—among which may be instanced the Killarney fern (*Trichomanes radicans*)—zoologists infer either that the forms lived on in this island, from the warm Miocene period to the more temperate Pleistocene times, which ousts the supposition of a continuous ice mantle; or that the temperature of the island during Pleistocene times was warmer than it now is, a partial ice mantle notwithstanding! The mingling of the remains of southern and northern forms in the cave deposits seems to increase the difficulties, though Professor Boyd Dawkins explains this by the retiring of Arctic forms southward before the extending ice cap, and the migration of southern forms northward during its temporary and final recessions. This suggestion does not seem adequate under the present geographical circumstances of the island, for Ireland was probably almost wholly covered with ice and *névé* for a prolonged period; and even in England northern and southern forms would have to find subsistence huddled together in the narrow space south of the Thames, and on the mountain-tops.

Irish Sea Soundings.

It is a striking circumstance, and one which seems to have an important bearing on this controversy, that shallower water exists between the coast of France and Ireland, by way of the Cornish coast, than in any other part of the Irish Sea or Bristol Channel. The figures, as taken from the Admiralty Chart, show that:—

---

* *Op. cit.*, pp. 115, 301, &c.

Between Cantire and Fair Head, deepest water is	70 to 80 fathoms.
Between the Coast of Down and the Isle of Man, ...	57 to 63 "
(From Isle of Man to Cumberland, .	21 ")
Between Waterford and Cornwall, deepest water is but	56 "
Between Cornwall and France, . .	56 "

There is no doubt that this great hollow was carved out when the land stood some hundreds of feet higher than at present, and probably in Pliocene times—for by river denudation only could the excavation have been wrought; and an elevation of 350 feet above the present datum, or low water, would connect the British Isles with the Continent; while an elevation of 500 feet would dry an area as far as 150 miles to the south of Ireland, where the Great Sole Bank is covered by no more than 85 fathoms of water.

Evidence that land stood some 350 feet higher than at present in recent times is, in the nature of the case, scarcely to be expected; though minor alterations of level, indicated in submerged peat, some 50 or 60 feet under present high water, is known, as in Dunworly Bay, on the Cork coast. A submergence of some 60 feet in the south of Ireland is unquestionable. If the detritus filling the river valleys of Cork, now partially submerged, be wholly recent valley gravels and alluvium, there would be proof in this of a very considerable submergence; even should the valleys be partially filled with glacial deposits, there may have been a much greater elevation than that for which we have actual proof, though not of sufficient duration, to admit of those deposits being completely scoured out, prior to the last submergence. Dr. J. Geikie holds that part of the German Ocean may have been dried since Glacial times.*

Possible Explanation.

Taking into account the bearings of the case as sketched above, the writer ventures to summarize the conditions, in a form which, so far as evidence met with in Ireland goes to show, may serve as a basis of explanation, satisfactory to geologists and zoologists alike—taking as his standpoint the belief in a continuous ice-mantle, extending uninterruptedly from Scandinavia to Cape Clear and the valley of the Thames, at one period of the ice-age. This assumption is not a bare hypothesis, but a conclusion arrived at by Sir A. Geikie, Dr. James Geikie, and others fully conversant with all the facts of the case.

---

* Great Ice Age, 3rd Ed., p. 354.

The conditions occurring successively would seem to be as follows:

1. Extensive denudation in Pliocene times which, amongst other results produced, hollowed out the Irish and St. George's Channels to a depth of some 400 feet below the present datum level; the coast line of the British area then standing at least the same number of feet higher than at present.

2. The approach of glacial conditions, during which migration of Arctic species, southward into Great Britain and Ireland, took place.

3. The establishment of those conditions, concurrently with the submergence of the area to such an extent that the glaciers descending from the valleys of Cumberland, West Lancashire, Antrim, and Down, met with marine conditions in the Channel, where *foraminifera* and other marine forms lived upon the sea floor, and mingled with the *débris* pushed out by the glaciers and dropped from floating ice.

4. A re-elevation of the region to such an extent as to re-make a land-connection between southern Ireland and England and the coasts of France, and possibly with that of Spain or Lusitania. Concurrently with this there may have been a decline of cold, giving increased evaporation from the neighbouring ocean, and increased condensation around the elevated Irish and British highlands, with a consequent great extension of *mers de glace*—all then merging, so as to form a continuous mantle as far south as Cape Clear and the Thames Valley. In the dried area to the south of this line mingled northern and southern forms, which, during the temporary recessions and advances of the ice-sheet, would have moved northward and southward, as suggested by Boyd Dawkins.*

5. The gradual vanishing of the ice-sheet, with alternating recessions and partial renewals, here and there damming up or bearing upon its surface vast sheets of water, into which were discharging torrential streams and rivers. Evidences for the existence and carrying power of the rivers are now found in the eskers; and the widely-extending stratified sands and gravels, so frequently met with throughout Ireland, testify to the magnitude of some of the glacial lakes.

6. Assuming, as of necessity, the obliteration of pre-glacial animal and vegetable life in the area which we now call Ireland, the links with south-western European fauna and flora are so strong, and of such a character, as to admit of little doubt that a land connection existed until recent times, and thus afforded a footing for migrants more natural and inviting than an ice-bridge. These established themselves in the country, during the decline of glacial conditions.

---

* The reader will perceive that the scheme here outlined is in accord with, indeed has been suggested by, Dr. Scharff's opinion, that an important congregation of life forms existed in south-western Europe, and probably in adjacent land now submerged.

7. Following the recessions of the ice, peat bogs were formed, and glacial deposits were, to some extent, cleared out of the valleys. Subsidence then set in, submerging peat around the coast, bringing about also a silting up of the valleys, and probably forming, but certainly greatly widening, the arm of the sea which divides the British Isles, as at present.

Physicists' Objections.

Physicists, it should here be premised, may object that depression of the land during the period of least glaciation, and elevation some hundreds of feet when the ice-accumulation was at its climax, is the contrary of what their branch of science requires. Against this, in the absence of distinct counter-evidence, may be set certain *cosmical* conditions which render the British region in some sense exceptional:—First, the elevation in Pliocene times, after a probably long period of submergence, with the formation of a plain of marine denudation; and without any *glacial* cause for the oscillations; secondly, the equally eloquent fact that an earthquake and volcanic belt existed along the Atlantic margin of our Continent, with a centre of activity in the North Irish and Scottish area of Eocene age, and centres of disturbance still extant in Portugal and Iceland, coinciding with the zone where the oscillations are known to have occurred.* Reverting to the question of migration, the conditions sketched above would admit of the incoming of southern forms into the south of England, and into Ireland, at a much later period than Miocene or Pliocene; and, should the elevation have continued, so that the narrowest possible land connection remained until the *mer de glace* partially or entirely retreated, there would have been no difficulty in the way of migration; the ancient forms of our domestic animals and the other mammals could thus have appeared contemporaneously with, or prior to, the first incoming of man. Dr. Scharff believes the horse, cow, sheep, and pig existed in Ireland during the period characterised by the use of Neolithic implements (well-shaped flints), which are especially numerous in the sands, gravels, &c., forming the raised beaches along the Londonderry and Antrim coast.†

---

* The question of oscillations of level indicated by raised beaches, submerged peat, and preglacial beach-deposits, has received much attention recently. Submerged peat under beaches and estuarine clays at Belfast is mentioned by Mr. R. Lloyd Praeger, B.A., B.E., *Proc. Roy. I. Acad.*, 3rd Series, vol. iv., pp. 30, 43. See also paper on "The Preglacial Raised Beach of the South Coast of Ireland," by W. B. Wright, B.A., and H. B. Muff, B.A., F.G.S., *Scien. Proc. Roy. Dub. Soc.*, vol. x. (N.S.), Pt. II., No. 25.

† Professor Ewart states that the animals accompanied man in the period mentioned—that of Neolithic implements. "Ireland," page 336. Mr. Knowles of the County Antrim, who has devoted much attention to questions connected with primitive man in Ireland, states his belief that "our earliest Neolithic inhabitants came here on foot." *Proc. Roy. Irish Acad.*, vol. iii., 3rd Series, p. 663.

SECTION III.

THE DRIFTS OF IRELAND AND THEIR RELATION TO THE SOILS OF THE FOUR PROVINCES.

CHAPTER XV.—Ulster.

It is proposed in the present section to give further information concerning the Drifts, as regards their distribution, general characters, and, when possible, their contents: for convenience of reference the details are arranged primarily according to the Provinces. In doing this, districts are successively taken up in each Province, which have certain leading characteristics, either as regards physical features—which affect the distribution of the Drift; or geological structure—which, as we have seen, affects their character and composition. The published geological Sheets* (scale one inch to the mile) comprised within each district, are also given—in order, except when grouped in accordance with the grouping adopted in the published Explanatory Memoirs. From these Memoirs the details concerning the Drifts have been drawn.

In the description of Ulster Drifts which follows, it will be seen that in the hilly tracts, where denudation of the superficial covering has been greatest, the agricultural worth of many acres is due to the existence of patches of Drift preserved in hollows; and in recesses and on the sides of some of the mountains. Along the valleys in these tracts the deposits sometimes reach 130 feet in thickness. A comparison of the description with the geological map will show that, in many places, the stubborn character which soils derived from clays, shale, and earthy limestone would have, is ameliorated by an admixture of other rock debris, as in the case of those occurring around Donegal Bay, near Omagh, and bordering Upper Lough Erne. It will also be seen that the transplacements of debris has enriched, to some extent, the soils which cover the Silurian tract of Cavan and Monaghan; and that by the same means the sand and gravel terraces frequently met with, as along the Dungiven Valley, are in certain places invested with increased agricultural value by a covering of Upper Boulder-clay. As against such advantages, the soils over portions of the limestone tracts are rendered less valuable by Drift derived from other sources, as at Ballintra, in Donegal; and along the hill-skirts on each side of Lough Erne. The sands and gravels above mentioned yield light indifferent soils. They owe their character, as well as their origin, to glacial circumstances.

---

* The Map of Ireland, on the scale of one inch to the mile, is divided into portions of suitable size for publication, by means of vertical and horizontal lines. Each division is known as a Sheet, and represents an area which is eighteen miles in length from east to west, and twelve miles in width. The Sheets are numbered consecutively from left to right in tiers, beginning at the north-west corner. Reference is made in Appendix to the detailed examination and mapping of Superficial Deposits, commenced in 1901 by the Geological Survey in Ireland. The Maps of the Dublin, Belfast, Cork, and Limerick Areas, are now completed, and on sale, together with accompanying explanations.

DISTRICT I.*—West Donegal, lying to the west of Lough Swilly, and of a line passing southward from thence to Bundoran by Lower Lough Erne.

Boulder-clay is extensively distributed in Glenfinn and Glendowan. Great banks along the head waters of the Finn and Swilly rivers show in some places a thickness of 50 feet; and remains of a boulder-clay deposit occur here and there at considerable elevations. Little is to be found to the north of the Muckish and Aghla range, though on the south-eastern flanks, the boulder-clay forms smoothly sloping tracts, which reach an elevation of over 1,300 feet.

Small areas of Drift occur at Dunlewy, Gweedore, Crolly, Tor, Dungloe, Lettermacaward, Aranmore, and other places; but in none of these places does the deposit appear to be of great thickness. In the Fanad region, bordering Lough Swilly, it is sparingly represented, filling hollows and inequalities in the low-lying ground; here, in the more extensive patches, it forms mounds and ridges.

Thick undulating deposits line the valley of the Owentocker river, south-west of Glenties; and a large part of the Carboniferous area, north-east of Donegal Bay, is covered with boulder-clay, chiefly disposed in oblong hillocks or drumlins. The islets which diversify the head of this attractive bay consist of such mounds partially submerged. To the east of Laghy village the hillocks of Drift rise to heights of 150 feet or thereabouts, above the brooks which flow between. Southward, about Ballintra, it is similarly disposed where it is widespread: though in this region it is usually thin and distributed in patches over the limestone floor. Large quantities are found east of Pettigo.

Along the coast, eastward from Bloody Foreland, the cliffs consist of brown clay somewhat sandy, abounding in gravel and enclosing blocks of all the local rocks, those of granite being mostly rounded and occasionally of very large size.

The boulder-clay along the Finn and Swilly valleys is generally of a bluish gray colour. It contains ice-scored blocks and fragments of schist, quartzite, and others derived from rocks to the eastward. The debris of mica-schist and quartzite intermingles with that of granite at Dunlewy and Aranmore; while about Gweedore, Crolly, Tor, Dungloe, and Lettermacaward, the deposits consist almost exclusively of granite debris, being a pale, buff-coloured gravelly clay, with pebbles and boulders.

---

* The district comprises Sheets 3, 4 9, 10, 15, 16; 5 (part of); 11 (part of); 22, 23; 24; 31, 32. The reader will please notice that in this and subsequent lists of Sheets, semicolons placed between Sheets or groups of Sheets are intended to show that an Explanatory Memoir is devoted to each Sheet, or group of Sheets, as indicated.

The area of crystalline schists, between Donegal Bay and Glenties valley, is clothed here and there with small deposits of light-gray tough clay, with a large admixture of gravel and blocks, all derived from the debris of the adjoining schists and the granite of Croaghgorm. In the Carboniferous area the Drift consists of brown stiff clay, becoming dark in the lower parts, with which mingle variable proportions of sand, gravel, and blocks of sandstone and earthy limestone; together with granite, dolerite, and metamorphic rocks, which have come from the north-eastward. Small accumulations of Drift are scattered over the metamorphic region adjoining the Carboniferous tract around Donegal Bay, as east of Lough Eask, at the entrance to Barnesmore Gap, &c. Here, the Drift is of a yellowish brown colour, considerably sandy and gravelly, with boulders of local rocks. It is remarkable that some of the boulder-clay at the entrance to the Gap, even where it rests upon granite, contains only blocks and other debris of metamorphic rocks, proving that the materials have been transported south-westward. In the lower grounds and wider valleys of the Barnesmore mountainous regions, the tracts of peat generally conceal deposits of boulder-clay; for the streams, which cut through the peat and furrow the mountain sides, often cut through considerable thicknesses of Drift. Such accumulations on Gaugin Mountain reach an elevation of 1,200 feet.

The Drift east of Pettigo consists of brown and blue clay, with variable proportions of sand and gravel, and contains boulders of sandstone and impure limestone, also blocks and pieces of shale and rottenstone.

Moraines.—Deposits of sand and gravel, more or less distinctly stratified, and probably of morainic origin, form ridges and chains of hillocks, along the Gweedore valley, on its south side. Most of the boggy tract south-east of the Bloody Foreland mountain is underlain by gravelly clay, abounding in blocks of quartzite and granite. This deposit sweeps around Tievalehid Mountain, and is heaped up against the steep ridge of Carntreena. Similar accumulations extend along the northern flanks of the Errigal and Muckish range, and down into the ravine of Muckish Gap. A large accumulation of sand and gravel fills the recesses of Aghla Mountain, north-east of Glenties; and hillocks of similar materials are to be found in the valleys of this mountainous tract, extending from Aghla southward to Lough Erne; all such accumulations are probably of morainic origin.

Economic Clays.—Pipe-clay is to be found in Aran Island; and brick-clay, near Ballyshannon and Donegal (town).

District 2.*—Parts of Donegal, Londonderry, and Tyrone, lying between District 1 and the meridian through Limavady, and extending southward to the latitude of Lower Lough Erne.

Throughout the peninsula of Inishowen the Drift is in general thinly distributed, though it appears in considerable quantity in West Inishowen, and within the river valleys; and it rises to 1,000 feet above the sea level on the flanks of the hills.

South-east of Lough Foyle boulder-clay spreads over a large area, principally in the low ground; it is here of considerable thickness, for deep sections may be seen along the streams which traverse this area, flowing northward towards Lough Foyle.

Almost the whole area south-westward of Londonderry for some ten miles, is covered with Drift; in the valleys it frequently attains considerable thickness, and clothes the hill sides to a height of 900 feet in some parts. About Raphoe, and to the south-west of that place, the covering is not deep, and is chiefly made up of angular local debris.

S.E. of Londonderry.

In the region lying between Londonderry and Dungiven the Drift is pretty generally found, chiefly in the valleys, though it ascends the flanks of the hills to 1,000 feet elevation—1,300 feet on the slopes of the Sperrin Mountains. East of Dungiven, throughout the basaltic area, the Drift gives a smooth outline to the ground in the less elevated parts, diminishing in thickness with the ascent to the higher areas, where the underlying rock becomes frequently visible.

Boulder-clay overspreads a large part of the region lying between Lifford and Omagh, becoming thinner, and disappearing, upward on the slopes of the higher hills, Mullaghcroy, Bessy Bell, &c. It ascends these hills to an elevation of 1,000 feet, and although attaining considerable thickness in the valleys, many tracts in the lower ground are almost devoid of this covering.

In the country between Omagh and Draperstown, the Drift ascends to a height of 1,250 feet on the mountain flanks. Boulder-clay may be seen in sections near Draperstown and Slieve Gallion, merging downward into stratified sands and gravels, from which it is inferred that the former, in this locality, represents Upper Boulder-clay.* South-east of Omagh, in the country stretching between this town and Ballygawley, the Drift is but sparingly distributed, except towards the east part, in the limestone district. It usually forms gently sloping hills or undulating ground.

---

* Sheets 1, 2, 5, 6, 11; 12; 17; 18; 25; 26; 33; 34.

Along the Claraghmore valley, between Omagh and Drumquin, the boulder-clay forms a thick deposit in many places, and is disposed in irregular hillocks. It spreads northward over a considerable portion of the metamorphic ground bounding the valley on the north, and skirts the ridge west of Omagh, also formed of metamorphic rocks.

Around Omagh.

A glance at a geological map will show the great diversity of rocks which surround the town of Omagh. The Drift in its vicinity shows a corresponding diversity in character. At the town, and along the valley, westward, is to be found tough, brown, gravelly clay, with blocks of grit and some of limestone with fragments of schist and white quartz. Further south generally occurs tough reddish clay, here and there mottled, reddish, blue, and green, and enclosing blocks of red sandstone, dolerite, a few of limestone, and of mica-schist; and in the vicinity of Irvinestown, those of bright red jasper. South of Fintona, the Drift becomes almost entirely composed of well-rounded pebbles of quartz, schist, and quartzite, embedded in sandy clay, resulting from the disintegration of the rocks which form the higher neighbouring grounds. Throughout the Old Red Sandstone area eastward, the Drift consists of chocolate-coloured clay with blocks and fragments of local rocks.

North of Omagh.

Over the whole metamorphic region lying northward of Omagh, the Drift in its deeper portions consists of tough, gray or brownish clay, rarely showing stratification, containing numerous glaciated boulders of metamorphic rocks, other varieties being of rare occurrence, except near Victoria Bridge, where a band of red shale and red and yellow sandstone, with conglomerates, intervenes. Granite blocks are also to be met with around Raphoe embedded in the superficial Drift or resting upon it. In certain places the boulder-clay contains layers of sand and gravel, and is itself frequently gravelly. When the superficial covering is shallow it is observed to be specially stony, chiefly consisting of angular fragments of local rocks. Chalk flints are of frequent occurrence in the boulder-clay north of Culdaff in Inishowen, as far west as Malin Head. In this region an Upper Boulder-clay is to be observed, as at Inch Road railway station, where it rests upon beds of sand and gravel.

---

* Portlock, in his Report of Londonderry (p. 158), under the head of Tertiary clays, describes a purplish calcareous clay with boulders and shell fragments, occurring beneath gravelly boulder-clay and gravels, in the stream flowing by Muff (Eglinton), Faughanvale river, and in the streams separating Gortgar from Gresteelbeg, Ballykeen from Drumacarney, Drumrane from Mullagh, Ardinarive from Bovevagh, and Balteagh from Drumachose.

Boulder-clay varying from gray to chocolate colour, greatly compressed, and sometimes calcareous, underlies sandy materials a little way east of Fruit Hill, near Limavady.

Chocolate-coloured clay of a compact plastic nature, containing shells, exists in a few localities near to, and north of Dungiven. The boulder-clay in the basaltic region east of that town consists of brown clay containing somewhat worn blocks of basalt with pieces of mica-schist and quartz, and occasionally round chalk pebbles.

Sands and Gravels.

Sands and gravels occur along the greater part of the western shore of Lough Foyle, and in some places spread into extensive terraces, as at Kilderry, near Muff, in Inishowen. Smaller deposits of similar materials—chiefly of schist, quartzite, metamorphic grits and sandstone—occur on the shores of Lough Swilly. Chalk flints are also to be noticed in these gravels.

In the neighbourhood of Dunnamanagh and east of Lough Foyle, sand and gravel deposits also form important tracts, and are in some parts of great thickness; they ascend the slopes of Slieve Kirk to a height of 1,000 feet. Similar large tracts, which generally assume a flat form of surface, are found eastward of the last-mentioned region, and sometimes extend to the hill tops, as on Sistrakeel Top, five miles south-west of Limavady. The most remarkable are those extensive flats which spread over most of the district around that town.

Terraces of sand and gravel extend southward by Dungiven, and form remarkable features a few miles south of the town. Deep sections in sand and gravel occur in the banks of Dunlogan River, near Moneyneany, eight miles south-south-east of Dungiven.

The gravel here contains pebbles of mica-schist up to nine inches in diameter, and is derived chiefly from the Carboniferous beds of the area. In the Dunlogan sections the gravels are cemented by deposited calcareous and ferruginous matter, so as to form a hard conglomerate. Southward of Draperstown sands and gravels are sometimes seen to overlie boulder-clay. They form conspicuous terraces, probably of morainic origin, in the larger valleys, and rise to heights of 1,000 and 1,200 feet. A remarkable line of gravelly flat-topped hillocks occurs on the northern flank of Mullaghbane Mountain, running west-south-west, and forming a rude terrace at a height of 1,000 feet. Extensive terraces are also found on the slopes of Mullaghcarn, at an elevation of 900 feet. Deep sections through such a terrace are laid open in Altaraven Glen, near Gortin, in that region; and westward at Newtownstewart a terrace of fine sand clothes the northern slope of Bessy Bell Mountain; hillocks of sand and gravel dot the Derg Valley along by Ardstraw, and a group of such hillocks forms a striking physical feature at the entrance to Baronscourt valley. Eastward of Sion village occurs a deep deposit of similar materials stratified—the pebbles in which are formed chiefly of Carboniferous sandstone. To the south-east of Omagh, sands and gravels are widely distributed, and are seen to overlie boulder-clay in stream sections, as, for example, near the cross-roads about four miles north of Ballygawley. They usually form flat-topped hills, terraces, and esker ridges. The flat forms are conspicuous near Pomeroy, in the wilder region lying a few miles north of Beragh, and in the elevated Old Red Sandstone district to the south. Ridges of sand and gravel are of frequent occurrence, particularly at Brackey, three miles north-west of Omagh; at Clogheny Church, a little north-west of that town; and at Eskragh, seven miles west of Ballygawley.

Eskers.—In addition to those just mentioned, which are, in some instances at least, true eskers, a striking sand and gravel ridge known as the Darvagh Esker, runs from a point six miles south-west of Draperstown, in a south-westerly direction, along Darvagh Water and by Broughderg; another, probably the continuation of the former, extends south-westward by Tiebane, as far as Lough Doo, and forms a tortuous and conspicuous ridge. Other less remarkable ridges occur further west, as near Creggan; and, of the group of sand hills which occurs near Limavady, one running northward in Roe Park—"the Mullagh"—is probably an Esker-ridge.

Economic Clays.—Potters' clay occurs near Fintona; and Brick-clays, on the borders of Lough Swilly, and at Omagh, Strabane, Gortin, and Ballygawley.

DISTRICT 3.*—Antrim, Down, Armagh, and parts of Londonderry, Tyrone, and Louth, lying to the east of the meridian through Limavady, and extending southward to Dundalk Bay.

In the extreme north of Antrim the Lower Boulder-clay consists of ochreous and brown clayey detritus containing glaciated boulders of basalt, with which intermingle those derived from other rock Formations represented in the northern part of the county.

---

* Sheets 7, 8; 13; 14; 19; 20; 21, 28, 29; 27; 35; 36; 37, 38; 47; 48; 49, 50 59; 60, 61, 71, 72; 70.

Amongst the rock fragments usually met with may be mentioned, besides basalt, chalk, flint, quartz, mica schist. Occasionally the boulder-clay shows a partially stratified arrangement, and sometimes it encloses irregular seams of sand or sandy clay. On both sides of the deep valleys opening upon the coast at Glenarm and Carnlough, deposits may be seen. That at Doonean shows a depth of 60 feet, consists of basaltic detritus, stones embedded in ochreous clay, and contains a large percentage of limestone (chalk) blocks. It is remarkable that, though the Chalk outcrop ascends no higher than 250 feet on the escarpment in this locality, the limestone blocks derived therefrom are found at 450 feet above the sea level, and to the west of the outcrop. The boulder-clay arranges itself in great banks or hog-backed hillocks, drumlins, inland west of Carnlough; the prevailing trend of their longer axes being west-south-west.

Drifts cover the low-lying country along the shores of Lough Neagh, and the sloping ground from the shores of Belfast Lough to the base of the basalt escarpment. It also spreads over Island Magee—indeed only the higher elevations are devoid of Drifts. Two members of the Drift series are frequently present throughout Antrim; and a third, Upper Boulder-clay, is sometimes to be seen. The following section has been met with in Massarene Park:

Upper Boulder-clay, containing water-worn pebbles and sand, ...	5 feet.
Interglacial sands—fine silt and sands stratified, .	6 ,,
Lower Boulder-clay, containing basalt blocks and other stones (bottom not seen), ...	?

South Antrim

The Lower Boulder-clay, in this part of Antrim, contains with debris of basalt, pebbles of chalk, and pieces of lignite and fossil wood. It sometimes reaches a depth of 50 feet here, and even then occasionally supports a covering of 10 to 20 feet of sands and gravels.

Upper Boulder-clay is to be observed in certain places west of Lough Neagh, where it forms the summits of some Drift hills more elevated than usual, in that locality. Thus, it is to be seen on the summit of Mullaghdun, north of Dungannon; also on that of Castle Hill, at the town, where the Upper Boulder-clay was penetrated before sands and gravels were reached, in searching for water. It is also to be seen in the townland of Coolhill; it has been therefore inferred that this member of the Drift series once had a wide extension in the region west of Lough Neagh.

South-east of this lake, the Lower Boulder-clay consists of reddish brown and gray clay, with glaciated boulders of basalt and fragments of Silurian grit, sandstone, chalk, and flint—more rarely also those of mica schist, gneiss, quartzite, crystalline limestone, &c. Over the New Red Sandstone outcrop the boulder-clay is of a very bright red colour, and sandy, while, over the Silurian area, it is dark brown, with a preponderance of boulders and fragments of grit.

Armagh and Down.

Near the railway junction at Armagh, limestone boulder-clay is cut through, presenting a section 50 feet in depth. The deposit consists of reddish-coloured marly clay, with large, more or less rounded blocks of limestone, which are polished and scratched. Clayey Drift to a depth of 30 feet rests upon a deposit of gravel and local rock debris—limestone, red and yellow sandstone, &c., north of M'Broom's Hill, on the Great Northern Railway.

Around Newtownards, the boulder-clay is of reddish and brown colours, and contains boulders of Silurian rock, basalt, dolerite, and fragments of chalk.

In the south-eastern portion of Down the boulder-clay consists of exceedingly hard, compact, bluish clay, shading upward into more porous clay of a light brownish colour. The prevailing boulders consist of Silurian grits, with which are mingled those of basalt diorite, mica-trap, and limestone; together with pebbles of chalk and flint. Occasionally the clay contains layers of gravel and sand, though stratification is rarely observable. Similar boulder-clay is to be seen in the extreme south of the county; and it is frequently arranged in the form of drumlins. These in the adjoining area about Castleblayney show unusually abrupt and irregular outlines. Vestiges of boulder-clay have been met with on the slopes of Slieve Gullion, up to 1,100 feet. To the south-east of this mountain, the Drift forms some remarkable longitudinal ridges, the largest and most conspicuous of which is Drumminatee. In this locality the trend of the ordinary drumlins is north-west and south-east.

The Drift line on the north side of Anglesey Mountain in the Mourne region is 950 feet, while on the south side of Clermont Carn it rises to over 1,400 feet; and on the Col, between Slieve Foye and Barnavave, in the Carlingford region, it rises to 1,200 feet.

In the area adjoining the granite, blocks of this rock become abundant in the boulder-clay, particularly in the uppermost portions. Drifts have accumulated to a great depth in the low-lying grounds of the mountainous regions. Thus, the Altboy river cuts its way through a thickness of 130 feet at one point.

Sands and Gravels.

Stratified sands and gravels have a very wide distribution throughout this district. They may be seen resting on Lower Boulder-clay in sections along the Bann; and eastward towards Ballymoney, Dervock, and Stranocum they are observed to increase in thickness, and merge upward into a partially stratified clay with boulders. A similar arrangement of the Drift is to be observed along the Carey river, in the north, south-eastward of Toome, and elsewhere in the vicinity of Lough Neagh, where the Upper Boulder-clay is spoken of as "red till." In some cases the sands and gravels rest upon the basalt without the intervention of Lower Boulder-clay.

In the northern part of Antrim the gravels show pebbles of the following rock varieties, viz., basalt, chalk, flint, and metamorphic rocks. West of Lough Neagh, the number of varieties noticed is considerably larger; the following list is given by Mr. Hardman, late of the Geological Survey:—

Basalt.
Syenite.
Diorite.
Mica trap.
Blue felstone.
Pink granite.
Yellow sandstone.
Red micaceous do.
Carboniferous shale.
Chalk flint.
Chalk.

Extensive deposits of sand, with some gravel, are to be seen along the Lagan Valley, as well as east and west of Lough Neagh, and northward towards Ballymoney; they contain layers of fine red plastic clay, adapted to pottery and brick-making. Several important brickyards are established on these clay-drift deposits, along the Lagan Valley, especially near Belfast.

These stratified deposits occur sparingly southward of Armagh, though small irregular mounds are to be met with there; and a deposit of fine sand occurs near Keady.

The corresponding deposits west of Portadown contain several of the above varieties, mingled with pebbles of limestone silicified (fossil) wood, and ironstone nodules.

Of the stratified deposits in South-east Down the coarser gravels are occasionally transformed into a fine conglomerate by deposition of Carbonate of Lime from the percolating waters, as may be seen at Killough. In this region the relations to be observed between the Lower Boulder-clay, the sands and gravels, and a raised beach, are well marked.

Eskers.—Sinuous ridges of sand and gravel are to be seen in many places throughout this District, as far north as the boggy flat between Ballymoney and Ballymena, one occurring about halfway between those towns. Eskers are also to be seen in the large bogs between Kilrea and Bellaghy, in Londonderry. One at Ballymacpeake Lough is especially noticeable. It may be traced eastward in a line towards similar ridges, which occur in the vicinity of Ballymena: at certain points it is 20 feet in height, and varies in width from a few, to 80 yards. South-east of Lough Neagh, another somewhat remarkable ridge is traceable to Red Hill westward for two and a half miles, from a point north of Lisburn, and another southward, from Dunmurry. Other eskers occur in the neighbourhood of Dundonald, in East Down.

Economic Clays.—Potters' and Brick-clays south of Coleraine along the Bann, at Castledawson, near Antrim (town), Belfast, Castle Espie, Armagh (town), Castleblayney, and Carrickmacross.

DISTRICT 4.*—Cavan, and parts of Tyrone and Monaghan—extending southward from District 2 to the boundary of the Province.

North of Loughs Melvin and Macnean, and eastward towards Lough Erne, the low ground is covered with boulder-clay, which is disposed in low ridges. Such ridges are prevalent along the valley of Upper Lough Erne, where, though the Drift has a wide distribution, it does not seem to be very deep; the underlying limestone strata appear at many points. Eastward the deposit thins out and almost disappears over a large area north of Newtownbutler. Along the valleys stretching north-eastward by Fivemiletown and Monaghan, much Drift appears in the low grounds, and in the glens which traverse the intervening high ground. The tableland of Slieve Beagh south of Clogher, and the elevated tract north of that town, are almost devoid of Drift; it appears only in isolated patches. Between Clones and Castleblayney it is arranged in regularly shaped hillocks—drumlins, which are disposed with their longer axes directed northward, over the Carboniferous area, and east-north-eastward over the Silurian area.

Boulder Clay.

The boulder-clay generally consists of stiff blue and, sometimes, reddish clay, containing boulders and pebbles of rocks met with in the District, which are usually ice-scratched. Reference to the

---

[*] Sheets 44; 45; 46; 56; 57; 58; 68, 69; 79, 80.

map will show that in most of the low ground, where the Drift lies, limestone is the prevailing rock. Accordingly, limestone blocks are prevalent in the boulder-clay. With these are mingled those of sandstone, which are usually yellow.

The boulder-clay in the country west of Lough Erne, and around that lake, is in many places particularly argillaceous. It yields subsoils which are so impervious as to be very difficult to drain, and soils which are wet and marshy. In certain places the clay is of such a character that it might be utilized for pipe and tile-making.

To the east of Enniskillen the Drift is of a chocolate-brown colour, usually pebbly, and contains abundant debris of the Old Red Sandstone. Elsewhere the Drift is blue, brown, or yellowish, though occasionally red, as at the side of Colebrooke demesne, and at Oldtown wood, north-west of Maguiresbridge, where it contains pieces of flaggy purple sandstone, as well as blocks of grit and limestone.

Near the sandstone areas, which generally form the high grounds on each side of Lough Erne, the Drift becomes more sandy than elsewhere, in this region, and contains, especially in the uppermost portions, a preponderance of sandstone boulders.

In the eastern portion of the District, near Caledon, much of the Drift is derived from the New Red Sandstone which underlies the superficial deposits in that part. It is accordingly of a bright red colour. Numerous sections of this Drift along the River Blackwater, north of Caledon, show boulders of reddish and gray grit, basalt, and limestone. To the south of this region the Drift is of the usual kind that overlies limestone, until the Silurian area is reached. Here its character gradually changes to that of brown pebbly clay containing boulders of local grits. Such boulder-clay forms great undulating mounds south-westward over the Silurian tract about Castleblayney, Ballybay, and Cootehill. There are in this tract some rugged, rocky areas, which are almost without a Drift-covering, as, for example, north and north-east of Shercock, east of Butler's Bridge, &c. Throughout the lake district, including the country around Cavan, Belturbet, and Ballyconnell, the boulder-clay is arranged in more or less regular low hills.

In the extreme south of this District (southern portion of Cavan), boulders of granite mingle with those of Silurian rock, near Kilnaleck; and in the region of Ballyjamesduff, and Virginia, the boulder-clay forms a thick mantle over a wide area, limestone boulders making their appearance amongst the Silurian detritus to the south of the latter town, where the limestone area of Central Ireland commences.

Esker Gravels.—West of Lough Erne, the only stratified deposits which have been described are those observed north of Ballyconnell, where the road to Derrylin cuts through banks of stratified gravel consisting principally of limestone, and much used for road metal.

The Drift between Fivemiletown and Colebrooke is composed of gravel arranged in linear hills. At Corralongford Mill the gravel contains numerous dark gray limestone boulders. At Gortmore and Kiltermon Church, openings show round pebbles of pale and purple sandstone, subangular fragments of limestone and boulders of the same, white quartz pebbles, and small basalt boulders.

Between Clones and Castleblayney sands and gravels have been noted at a few points. They are seen to overlie boulder-clay four miles north-west of Monaghan, on the road going north from Scotstown. Gravel ridges also occur near Smithborough, and at Kilvilly Lough and Black Lough, north-east of Roslea.

In the eastern portion of the District, stratified sand and gravel occur south of Tedavnet (five miles west by south of Glaslough), where they attain a thickness of twenty feet; and a series of irregular mounds of gravel may be noticed about four miles north-west of Glaslough.

Economic Clays.—Potters' clay is reported to occur at Tedavnet, and Glaslough; and Brick-clay near Drumane, south of Enniskillen, on the borders of Upper Lough Erne, near Clones and Monaghan, and at Bailieborough.

CHAPTER XVI.—CONNAUGHT.

Throughout this Province, the Drift chiefly ocupies the low ground, though it rises in exceptional instances to 1,500 feet on the hill sides, and there usually forms soils of higher value than those native to the locality. Its disposal in the peculiar hog-backed hillocks, or drumlins, which prevail in many parts of the low-lying areas, renders tillage extremely inconvenient. The distribution of glacial material derived from poor sandstone districts, as over the limestone south of Castlebar, and over limestone boulder-clay near Westport, has already been commented upon; and the disadvantage of this is not counterbalanced by the transplacement of limestone debris; though such occurs to some extent over the metamorphic region to the north of Castlebar, where the transported limestone boulders are utilized for burning.

DISTRICT 1.*—Counties of Leitrim and Sligo, and the portion of Roscommon lying to the north of Boyle.

The Drift in this region is found chiefly in the lower grounds, though sometimes to be met with upon the hill tops at elevations up to 1,500 feet. The features being generally steep-faced, they do not favour the repose of transported materials upon their flanks, which are frequently clothed with talus, or local rock debris. The boulder-clay is usually blue, occasionally yellow, and contains numerous glaciated pebbles and blocks, amongst which those of limestone and sandstone predominate; in several places it forms the characteristic hog-backed mounds or drumlins.

South-east of Sligo Bay in the ground where Sligo and Leitrim adjoin, similar mounds prevail, the longer axes of which trend westward near Drumkeeran, north-eastward in the Larkfield valley towards Manorhamilton, and north-westward about Thornhill and Annaghmore. The colour of the Drift is brown, slate-coloured, or blue; and it contains numerous blocks of limestone, and variously coloured grits, many of which are smoothed and striated. As the slopes of the Laragh hills are approached and ascended, the boulder-clay is observed to become much darker and to contain fragments of black shale from the local strata, which are especially numerous in the lowest portions.

Near the foot of the Ox Range, on either side, gravelly drift prevails, and Drift of the same character is to be observed near Seafield, at the foot of Knocknarea.

A large number of metamorphic blocks, many of large dimensions, are scattered over the country to the north of the Ox Mountains, either resting on limestone, or upon or embedded in, boulder-clay.

---

[*] Sheets 42, 43; 54, 55; 66, 67; 78.

North of the Ox Mountains.

West of Ballisodare Bay the Owenduff River, which passes by Dromore, cuts through a great thickness of boulder-clay, just south and west of King's Mountain. A vertical section, 100 feet in depth, was measured in the river bank. The materials of this deposit are almost exclusively derived from metamorphic rock, though they are cemented in some places with carbonate of lime. The head waters of the Easky river also cut through a great thickness of boulder-clay. From such evidence it has been inferred that in the wide peat-covered tract skirting the Ox Mountains on the north, a considerable thickness of Drift lies concealed beneath the bog, at elevations of 400 feet to 800 feet above the sea. Over the Carboniferous rocks, north of the range, Drift is but sparingly represented, and consists chiefly of limestone and sandstone debris.

South-east of the Ox Mountains around Tobercurry the character of the Drift partakes largely of that of the strata which it conceals. The limestone is divisible into Lower, Upper, and Middle—the last of which, "Calp," is notably earthy. It is noticeable that the Drift covering this last contains proportionally more clay than that which covers the Lower and Upper Limestones. The matrix of the lower portion of the boulder-clay in the locality is remarkably tough and hard, as indeed is usually the case when containing a considerable proportion of argile. Even when the argillaceous material exists in scarcely discernible proportion, and the "boulder-clay" is made up chiefly of angular gravel, it is so compacted in certain places that only with the aid of a pick can it be dug out.

In the ground about Curry the Drift forms an undulating mantle; towards Gorteen it assumes the disposition of drumlins, which trend westward towards Banada, and northward towards Bunnanaddan. Drumlins also prevail north of Tubercurry, with a northward trend, which they maintain even where the Drift ascends the slopes of the Ox Mountains.

In the region lying around and to the south of Lough Allen, the boulder-clay is made up chiefly of the debris of the local strata, the boulders being for the most part striated and polished. A great deal of rocky Drift exists along the slopes of the Old Red Sandstone ridge, which, to the north of Boyle, forms the Curlew Hills. In the lower grounds drumlins are of common occurrence, maintaining for the most part a north-north-westerly direction.

In addition to the gravelly Drift already mentioned as skirting the Ox range in certain places, sandy Drift, representing Upper Boulder-clay, occurs elsewhere in this region. Thus, the uppermost layer of Drift about Curry, and southward by Charlestown, is sandy, and contains numerous sandstone pebbles and some angular sandstone boulders.

Eskers.—Accumulations of sand and gravel exist in the valleys of the Ox range, most of which are doubtless of moraine origin. In the valley south of Easky Lough, however, the sand and gravel (consisting chiefly of limestone material) assume the eskery form. A striking esker, consisting of the same kind of sand and gravel, runs westward by Banada, flanked on either side by bog. Sands and gravels have also been observed at Red Hill, west of Boyle, south of Ballymote, and along the north-west shore of Lough Arrow.

A remarkable terrace of sand and gravel extends from Lough Gill to Ballisodare Bay. It is devoid of metamorphic erratics, which are so plentifully distributed elsewhere over the locality; from this, and because its highest level is about 70 feet above the sea at present, it may be inferred to have been formed, like so many other similar deposits, in a glacial lake.

Economic Clays.—Potters' clay and Brick-clay at Leitrim (town) and on the margin of Lough Gill. Brick-clay, near Carrick-on-Shannon, Dromahaire, near Boyle, and bordering Lough Allen.

DISTRICT 2.*—North Mayo, lying to the west of District 1, and north of Clew Bay.

Boulder-clay covers nine-tenths of the district lying to the south of Killala Bay. It consists of dark bluish pasty and tough clay, with well rounded and striated blocks of limestone; and is frequently arranged in drumlins. North west of Castlebar limestone boulder-clay of great depth covers the Metamorphic and Old Red Sandstone ground: the boulders in this Drift are freely availed of, for lime-burning, by the tenant-farmers.

In North-west Mayo—the district of Erris—the divisions of the Drift, which here and there are to be observed, are Lower Boulder-clay, and sand and gravel, with erratics. Numerous sections in the stream courses along the coast, show forty to fifty feet in depth of Lower Boulder-clay. This is of brownish colour and unstratified, partaking largely of the nature of the disintegrated local strata. In some places it graduates into hard blue compact *till*, with few large but many small boulders, some of which are scratched. Shells and shell fragments were found in these clays at four different localities. The Lower Boulder-clay is extensively distributed, and it contains scratched boulders and fragments of rocks, which occur *in situ* several miles to the south.

Over the boulder-clay come sands and gravels, which seem to be sparingly distributed; they have only been seen in the river valleys where these debouch upon the coast. The following section (Fig. 60)* represents their mode of occurrence and thicknesses at one point:—

---

* Sheets 39, 40, 51, 52; 41, 53, 64; 62, 63.

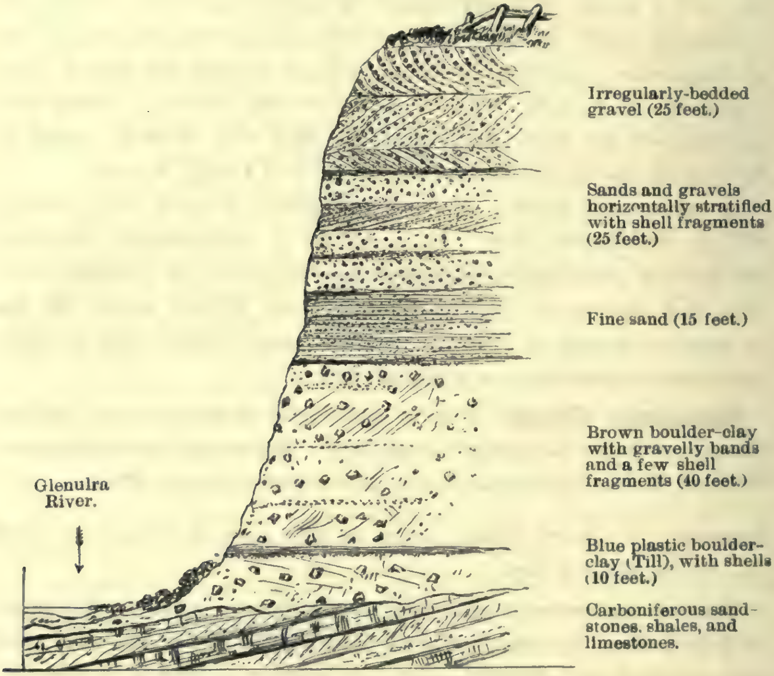

Irregularly-bedded gravel (25 feet.)
Sands and gravels horizontally stratified with shell fragments (25 feet.)
Fine sand (15 feet.)
Brown boulder-clay with gravelly bands and a few shell fragments (40 feet.)
Glenulra River.
Blue plastic boulder-clay (Till), with shells (10 feet.)
Carboniferous sandstones, shales, and limestones.

Fig. 60. Post-Pliocene Deposits, Glenulra River, Co. Mayo.

East of Blacksod Bay a large tract of peat conceals undulating Drift, which consists mostly of debris of metamorphic rocks, with an admixture of sandstone detritus. Much Drift also occurs in the low ground and valleys around and to the north of Newport, the nature of which varies according to that of the rock which it conceals. Amongst the contents may be noticed blocks and pebbles of Old Red Sandstone, and Carboniferous conglomerate and sandstone, schists, quartzites, limestone, a few of granite, and fragments of chert.

A section of Drift seen to the south of Fahy Lough, near Ballycroy, shows stiff boulder-clay containing scratched boulders of schist, red sandstone, and conglomerate, overlain by coarse gravel and sand.

A large part of the eastern portion of Achill Island is covered with sandy Drift, consisting chiefly of red sandstone debris, and containing blocks of conglomerate schist and quartzite. Great banks of boulder-clay, from forty to a hundred feet in depth, line the coast on the north side of Slievemore mountain; and the peat-covered area around Dooagh in Achill shows Drift in the stream courses, which consists chiefly of metamorphic rock detritus.

---

* From Explanation of Sheets 39, 62, p. 20

In many other places, as about Newport and to the north of Castlebar, the upper layer of Drift is sandy; and such Drift, with numerous boulders of red and yellow sandstone, may be traced southward by Ballyhean towards its origin in the sandstone tract north of Lough Mask. This deposit has been mentioned in Sections I. and II. as probably representing the Upper Boulder-clay.

Eskers.—In addition to the sands above mentioned, other sandy deposits have been met with in this region. A well-defined esker runs northward along the valley of the Moy at Foxford. It breaks up into a number of hillocks, but again re-forms, and continues its course towards Ballina, before reaching which place it divides into two branches. It is formed chiefly of limestone sand and gravel, even when resting upon the granite and metamorphic rocks near Foxford.

Somewhat similarly arranged deposits of sand and gravel—probably moraines—are frequent near Corick, in the Corslieve region. In this range of hills moraines dam the drainage in several smaller valleys and cooms, forming mountain tarns.

Economic Clays.—Tile-earth near Ballina; and Brick-clay near this town and Swineford.

DISTRICT 3.*—South Mayo and West Galway, stretching between Clew Bay and the Aran Islands, and lying to the west of Lough Corrib.

Lower Boulder-clay, stratified Drift, and moraine accumulations are to be met with in the area south of Clew Bay. The first mentioned is to be seen in the lowermost portions of the sections along the coast, where, however, the chief portion of the Drift is stratified; and the stratified portion of the Drift graduates upward into moraine matter.

The numerous islands in the eastern part of Clew Bay are hog-backed hills, drumlins, with their longer axes directed westward; and the most westerly of these islands have their seaward portions cut away, so as to present nearly vertical faces toward the ocean. They consist almost wholly of blue and brownish gravelly limestone boulder-clay, though this is covered with yellowish porous sandy boulder-clay of greater or less thickness, with blocks of sandstone and grit and some metamorphic rock debris.

Limestone *till* occurs in the lowest part of the Drift sections, to be seen in the stream courses half a mile south of the shore line of Clew Bay, west of Lecanvy. West of Louisburgh, the Drift forms cliffs in parts 130 feet in height, in which the materials are devoid of stratification. Numerous blocks of sandstone and shale occur in this boulder-clay, and well-rounded blocks of limestone, the whole being cemented by red argillaceous paste. Few granite boulders occur therein, though they are numerous along the shore.

---

* Sheets 73, 74, 83, 84; 93, 94, 103; 104. 113; 105.

The uppermost Drift, south of Louisburgh, is composed of debris from the country to the south, chiefly grits from the Mweelrea mountains, and pebbles of felsite from the same region. Numerous blocks of granite from the neighbouring Corvackbrack hills strew the ground in this locality, where the Drift forms an undulating covering. Curious intercalated layers of laminated fine clay, "book clay," are to be seen in the stratified Drift which forms the cliffs south-west of Louisburgh.

Boulder-clay.

Between Gowlaun and Renvyle, near the entrance to Killary Harbour, on the south side, occurs a great accumulation of Drift, chiefly stratified, upon which the sea has made inroads, forming cliffs from fifty to a hundred feet in height. This Drift contains innumerable ice-dressed boulders. Elsewhere, to the south of Killary Harbour, very little true boulder-clay occurs, the accumulations of debris, where found, being chiefly of moraine or "glacialoid" character. A few patches of boulder-clay occur in the vicinity of Cashel House and at other points in South Connemara, as at Barna House and Tonabracky. Limestone boulders have been found in some of these patches. They contain besides, blocks and fragments of gneiss, mica schist, granite, &c., which must have travelled considerable distances, as may be judged from their being rounded, polished, and scratched. Even when limestone fragments do not intermingle with other detritus in this boulder-clay, it is often calcareous and effervesces with acids.

In the lower country near Lough Corrib the usual Drift is boulder-clay, containing glaciated blocks, which are embedded in a clayey matrix. Near Galway, the boulders are mostly of limestone, and the boulder-clay is sometimes arranged in drumlins; much of the Drift of the region is rocky—limestone, granite, and metamorphic detritus intermingling.

In the Aran Islands a thin deposit of boulder-clay exists in shallow hollows; in two places it was observed to contain polished and striated blocks of limestone, granite, and metamorphic rocks; the latter varieties not occurring in the islands, must have come from the neighbouring mainland or the sea-bottom intervening. Numerous scattered blocks of these varieties occur on the high as well as in the lower parts of Aran, and may indicate that an extensive Drift-covering formerly existed there.

Sands and Gravels.

Throughout the district here under notice, stretching between Clew and Galway Bays, the stratified Drift, which may represent Upper Boulder-clay or Middle Sands and Gravels, graduates upward in certain places into moraine Drifts. Moraine accumulations are of frequent occurrence in the valleys and on the slopes of the Mweelrea, Formnamore, Maamturk, and other Connemara groups. Occasionally they dam the drainage and form mountain loughlets. Much rocky Drift has been noted along the Clifden and Oughterard valleys, and on the south of Killary Harbour, near Leenane.

Interesting terraces, presenting striking regularity of deposition, now covered with peat, have been observed on the north side of Formnamore range—in the Erriff River valley, and to the west of Lough Glenavough These terraces are formed of sand and gravel, and slope from north-east towards south-west, ranging from 200 to 370 feet above the sea ; and have been supposed by Mr. G. H. Kinahan, equally with similar terraces in Clare, Limerick, Kerry, and Cork, to indicate submergence of the land to this extent. It is possible that they are deposits from glacial floods, in lakes temporarily formed, during the period when the great expanse of land ice was vanishing from the district.

Esker.—Sand and gravel form a ridge extending westward by Lough Ross from the shore of Lough Corrib, some nine miles north-west of Galway.

Economic Clays.—Pipe-clay and Potters' clay, at Galway (town).

DISTRICT 4.*—South-east Mayo, East Galway and Roscommon—extending from Districts 1, 2, and 3 to the Province boundary.

The boulder-clay throughout this district consists of the debris of underlying rock, limestone materials prevailing, and it is usually gravelly. Where it contains a considerable admixture of clay, the matrix is peculiarly hard and tough. This argillaceous Drift is usually very impervious. Percolating waters sometimes leave a deposit of carbonate of lime in the gravelly drift, which cements its contents and renders it exceedingly hard and difficult to excavate.

In the region about Castlebar the Drift is disposed in drumlins, some of which are half a mile in length. Three or four hundred of these were reckoned in the district mentioned, separated from each other by bog, or flat-lying Drift, with here and there patches of exposed limestone.

---

* Sheets 75 ; 76, 77 ; 85, 86, 87 ; 95 ; 96, 97, 106, 107 ; 115, 116.

The boulders are usually polished and well striated. Over the sandstone areas sections of the Drift show boulders of sandstone, which are usually not rounded, many being quite angular. Limestone boulder-clay has, however, been noticed in the lower portions of the Drift in the tract of sandstone and igneous rock between Charlestown and Ballaghaderreen.

Limestone Boulder-clay.

Though the limestone boulder-clay just mentioned may represent the Lower Boulder-clay, a distinction between an upper and a lower, can be established in comparatively little of the Drift of the district. Much exists which does not possess the usual characteristics of the Lower Boulder-clay, but it cannot be said to belong to the Upper. Sandy Drift, with numerous sandstone boulders, many of which are angular, is to be seen near Kilkelly, in Mayo, and it extends westward towards Swineford. Similarly, sandstone debris from the Ballinlough, Sleive Dart, and Mount Mary (Creggs) sandstone tracts, is scattered over the limestone areas adjoining. In these cases it is probable that the debris mentioned, represents the Upper Boulder-clay, as Professor Hull has suggested with respect to the assemblage of angular sandstone blocks seen at Kilkelly. A comparison of the circumstances which here prevail with those of the Mount Mary region near Roscommon confirms the conclusion. Thus, a sandy clay with angular blocks traceable northward for some eight miles from Kilkelly to Curry, in Sligo, covers limestone *till* near the last-mentioned place. Such debris also overlies limestone *till* in the valley of the Suck, at Castlecoote, west of Roscommon.

A series of drumlins occupies the ground between Loughs Mask and Carra. The drumlins possess a northward trend, and consist of local sandstone debris, similar to that which strews the ground northward by Ballyhean towards Castlebar.

Stony Drift occurs throughout much of this area, chiefly in the regions lying to the east of Lough Corrib. With limestone blocks, intermingles, in this Drift, detritus of Carboniferous and Silurian grits and metamorphic rocks. To the north of Lough Corrib blocks of conglomerate also abound in the Drift.

A group of mounds skirts the hilly ground between the western parts of Loughs Mask and Corrib. They are unusually large, and overlook the limestone tract eastward; and consist almost wholly of Silurian rock-debris.

Eskers.—Ridges consisting chiefly of limestone sand and gravel, are to be observed in various places throughout this district, mostly in its eastern part. Four striking eskers follow divergent courses in the northern part of Galway. They run north-east and south-west;

north and south; and one east and north-east. In the south-eastern part of the same county a remarkable group of promiscuously disposed hillocks occurs within a triangular tract abutting on the Shannon, eastward, and spreading thence to Kilfreekill and Marble Hill westward. The group seems to form the broken-up western termination of one of the great eskers of the Central Plain.

Economic Clays.—Pipe-clay occurs at Creggs and Dunsandle; and at Knockcroghery, between Roscommon and Athlone, another deposit of good pottery clay exists, which has also been worked to a great extent. No works are now carried on here save the making of pipes.

Bluish red plastic clay suitable for pottery, occurs upon the south-east flank of Coarse Top, in the townland of Curries, near Ballinlough. The deposit was extensively worked formerly, and was about three feet thick.

Brick-clay is found at Cushlough, near Ballinrobe; and near Westport and Portumna.

CHAPTER XVII.—LEINSTER.

Much of the Drift in this Province consists of sand and gravel, the finer clayey components, which might be expected to occur in limestone detritus, having apparently been washed out of it during its deposition in glacial times. The sands and gravels usually clothe the low ground, but rise in some places to great heights on the flanks and in the valleys of the Dublin and Wicklow Mountains; and, consisting for the most part of limestone debris, they impart increased fertility to the soils in many parts of East Leinster. The soils of the barley district of Wexford are of glacial origin, and in many places are rich in fine limestone detritus and shell fragments—materials which are quite foreign to the locality. Another advantage accruing from former glacial circumstances finds illustration in some soils of this Province; thus, the Calp, or very earthy limestone, which prevails throughout Dublin and Meath, would under other circumstances, be clothed with strong clays, cold, retentive, and workable with difficulty. Those existing in the region are, however, generally friable loams, more or less sandy through possessing an intermixture of other rock detritus. In the following detailed description, as well as Chapter XI., the reader will find some more information concerning the Drift soils and subsoils of Leinster.

DISTRICT 1.*—Louth and North-east Meath—extending southward to Balbriggan and westward to Kells.

Boulder-clay has a wide extension throughout this District. It overspreads the ground in an almost continuous mantle, except the hilly parts in the vicinity of Carlingford, and has been described as possessing an average thickness of twenty feet in the coast sections, while inland, it shows a depth of forty feet in a section at Mellifont.

The deposit is generally of a yellowish and reddish brown colour, changing to bright red where it overlies the New Red Sandstone south-west of Carrickmacross, and gray over the Carboniferous rocks.

The prevailing stones in this Drift are slate and hard grits—from the Silurian strata, which form the chief portion of the area—with an admixture of granite and basic igneous rocks near Carlingford mountain. Immediately north of Dundalk there is much limestone Drift, due to the existence there of small tracts of limestone. Again at Carrickmacross and west of Ardee, Drifts occur which are rich in limestone detritus. Near the latter place the Drift likewise contains blocks of basalt, as well as some of sandstone, and pieces of shale. On Red Island it shows a section twenty-five feet in depth, and has fragments and boulders of greenish gray grits, diorite, and limestone, the last being the most numerous.

---

* Sheets 70, 71; 81, 82; 91, 92.

Sands and Gravels.

Much gray sand, and limestone gravel, are found about Dunleer and Castlebellingham. Similar deposits are well seen in sections along the Rivers Boyne and Nanny, forming in most cases low ridges. The sand and gravel here, are seen to rest upon boulder-clay. Limestone gravels cover several square miles in the neighbourhood of Gormanstown.

Eskers.—At Bective House, near the southern margin of the present District, occurs a well-marked ridge, in which are enclosed very large limestone boulders. West of Drogheda the gravels contain grits and shales in addition to the limestone detritus. Such gravels form a ridge south of Julianstown.

Economic Clays.—Potters' clay at Kurik and Brownstone, south-east of Navan; and Brick-clay at Ardee, Drogheda, and Dundalk.

District 2.*—Bounded on the north by District 1 and Ulster—extending southward to the latitude of Parsonstown and the boundary of Wicklow; and lying between the Shannon and the Irish Sea. It comprises Longford, Westmeath, King's County, Dublin, and parts of Meath, Kildare, and Queen's County.

Boulder-clay.

The boulder-clay in the northern part of Longford shows a considerable variety in colour, texture, and contents. In colour it varies from blue to reddish and yellowish brown. In the deeper sections the till or lowest portion is usually hard tough clay; the uppermost frequently gravelly and friable. The contents indicate the variety of strata which, in this region, compose the crust. In many places limestone boulders predominate. With these are often mingled those of sandstone even over the limestone tract. Over the sandstone areas, sandstone detritus abounds. North of Drumlish the Drift contains pieces of Old Red Sandstone, limestone, and Silurian rocks; while south-east of the same town sections of the Drift are to be met with which show no limestone boulders. Around the town of Longford in its immediate vicinity, Old Red

---

* Sheets 79; 88; 89 90; 98, 99; 108, 109; 100, 110; 101; 111; 102, 112, 117; 181; 119.

Sandstone detritus mingles with that of Silurian rocks to form the superficial covering, while at some distance from the town limestone debris from the underlying strata, prevails. Near Longford the Drift includes a brick clay, which contains pebbles of Old Red Sandstone.

In the large area of central Ireland lying between Longford and Parsonstown on the west, and Kells and Kildare on the east, the Drift, which generally overspreads the entire area, is such as the subjacent limestone would yield. That the deposit is one of transport, however, is proved by its containing glaciated boulders: while some of sandstone, conglomerate, and igneous rocks also intermingle with the limestone debris to some extent, in different places, and fragments of Silurian rock are of frequent occurrence in the Drifts near Crossakeel and Kells, carried southward probably from the Silurian tract north of those places.

The boulder-clay is usually of a yellowish brown colour; and it is frequently represented by limestone gravel in which the argillaceous component is very scanty, if not practically wanting.

Limestone Gravels.

The gravels in the Trim district are seldom met with on ground higher than 370 feet, though in Summerhill demesne they are piled on the top of a hill of 464 feet elevation; and at Kilcock they reach an elevation of 481 feet. Over the flat ground bordering the Dublin mountains on the north, the average thickness of the Drift is stated to be twenty feet; a thickness of forty feet is unusual; but in the mountain glens it has accumulated to a depth of 100 feet.

In the County of Dublin the Drift consists of two deposits: first, a black or brown gravelly clay with well-rolled limestone pieces of various sizes; second, sand and gravel mostly of limestone pebbles, with a good deal derived from Silurian rocks. Pebbles of granite also occur, chalk flints and other varieties. The first is spread over the northern portion of the county up to elevations of 300 feet and 400 feet above the sea-level. In the southern part, the clayey Drift is covered with sand and gravel which are prevalent over the granite and slate ground. Gravel, with numerous pebbles of limestone, is found at 1,235 feet elevation on the Dublin mountains at Kilmashogue, and at lesser heights at neighbouring points.

The limestone gravels are also met with abundantly on the east side of the range, covered in some places with loam three to seven feet in thickness, as may be seen along the cliff-sections between

Dalkey and Bray, where alternating gravel and boulder-clay with shells, are well exposed. They may also be seen in many stream cuttings on the mountain slopes, as, for example, at Monastery, in the glen of the small river which separates Dublin from Wicklow, and shells occur in the section along this river at Vallombrosa.

A close examination of the Drifts in Dublin, East Meath, and North Kildare, reveals the fact that in many places a thin uppermost layer is present, which is not only porous and friable, of a yellow colour, but contains numerous sandstone fragments; while the main body of the boulder-clay beneath, consists almost wholly of limestone detritus, compacted into a hard, tough substance of a dark brown or gray colour, containing scratched and polished boulders and pebbles.

Eskers.—From what has appeared above, it will be perceived that the Drift, which covers the District here under notice, is more or less uniform as regards its contents. So much is this the case that references to it in the published Memoirs of the District are chiefly descriptive of the singular if unpretentious features which traverse the central plain from east to west, consisting of ridges of stratified sand and gravel, often with rounded boulders, for the most part of limestone. The following general description of such ridges is drawn verbatim from the Memoir which describes the area surrounding Athlone and Mullingar. The eskers "vary considerably in their composition, the same ridge being in some places made up of the coarsest materials, large and small, angular and rounded fragments, occurring huddled loosely together, sometimes bound together by a calcareous cement, and sometimes embedded in a matrix of coarse gravelly clay, whilst in others, a transverse or longitudinal section exhibits fine sand and gravel. Sometimes seams and cakes of very fine yellow clay occur." The town of Athlone stands upon an esker, part of which has been taken advantage of for purposes of fortification. And some other remarkable eskers are described *in extenso* in the Memoirs referring to this part of Ireland, but the descriptions do not sufficiently bear upon economic questions to warrant their reproduction here. It will suffice to mention a few particulars.

Eskers near Tyrrellspass.

Three main chains of eskers diverge from a point near Tyrrellspass, in Westmeath, one pursuing a direction west by north, towards Athlone, near to which place it breaks up into a number of isolated hillocks and eskers, appearing east of the Shannon; also, as previously stated, at the town; and, in great number, south-west of Lough Ree, in the southern part of Roscommon.

Another strongly marked chain runs due west to the Shannon, at the other side of which it again appears; and pursues its course westward by, and beyond, Ballinasloe. This chain bifurcates before reaching the Shannon, and the second branch runs southward along the east side of the river, to cross it at Shannonbridge, and to follow the line of the Suck almost parallel to the former branch of the esker chain, towards, but keeping to the south of, Ballinasloe.

A third chain strikes south-westward from Tyrrellspass, its course changing to west, before terminating in the great bog west of Tullamore.

The remarkable mound known as Violet Hill, in the County of Meath, rises to a height of ninety-five feet above the surrounding flat ground; and a remarkable ridge extends for six miles south-eastward from the town of Trim. Another well-defined ridge is to be seen at Mount Lucas, south-west of Edenderry. It is four miles long, and attains an elevation of fifty-nine feet above the low ground. A thin layer of clay or loam clothes the contents of this ridge: it may have been deposited there at the close of the esker's formation.

Eskers near Banagher.

In the south-western portion of this central District, numerous eskers are to be observed in the country around Geashill and Banagher. A notable ridge, known as the Newtown and Frankford esker, is traceable for a distance of twenty-five miles in a sinuous course westward near Parsonstown towards Banagher, until it resolves itself into a number of isolated hillocks three miles W.S.W. of the latter town. In one place it forms a curiously shaped gravel hill called Coneycarn, the summit of which is eighty feet higher than the adjoining bog.

Sands and gravels form the undulating tract known as the Curragh, in the vicinity of Kildare; and in this locality reach the great thickness of 100, or in places perhaps as much as 200 feet. The following description is transcribed from the Memoir accompanying the one-inch Geological Survey Sheet 120. "The Curragh consists of a number of undulating and somewhat irregular ridges, or eskers, having an elevation of from 150 to 200 feet above the plain. The eastern part of the principal ridge, called Long Hill, and north of Jockey Hall, is described as 'gravel containing limestone of both Carboniferous and Silurian ages, the latter common and full of fossils; also traps, and porphyries similar to those *in situ* on Grange Hill,' on which is the Chair of Kildare; and, with them, chert, red conglomerate, and sandstone. This gravel has been estimated by Professor Jukes to attain a thickness of 100 to 150 feet."

Economic Clays.—Potters' clay at Ballinamuck, east of Longford; Mountmellick; and at Tubberpatrick, north of Strokestown.

Brick-clays near Granard, Longford, Boyle, Castlereagh; margining the Shannon; and near Castlepollard, Tullamore, and Parsonstown.

A thick, highly argillaceous deposit (boulder-clay) occurs at Kill-o-the-Grange, which is utilized for brick-making and coarse pottery. Similar clays are to be met with along the Dodder River near Rathfarnham, and at Harold's Cross.

District 3.*—Including the portion of Leinster lying to the east of a meridian through central Carlow, and south of District 2.

The portion of this District which borders the Leinster mountain range on the west, is covered with Drifts, except in a few cases where hills of Silurian grit and slate appear. Drift was observed at elevations somewhat more than 900 feet higher than the sea-level. In general the ground above this height is devoid of these deposits.

The greater part of this superficial covering consists of limestone gravel; the uppermost portion, generally, either contains or consists of clayey detritus of local (Silurian) rocks. References have already been made to a section at Grange Con, which is an instance exhibiting this fact; it is equally illustrated by a section described in the Memoir accompanying Sheet 120, and to be seen at Newtown Great, three miles westward of Blessington, in which limestone gravel, fifteen to twenty feet in depth, is covered with clay six cr seven feet thick. The clay probably represents Upper Boulder-clay.

The gravel is occasionally to be seen resting upon boulder-clay, which at Barretstown consists of brown clay containing limestone pebbles, very large, and sometimes angular.

Sea-shells have been found in the limestone gravel near Naas at 380 feet above the sea-level. They were also found at Ballymore Eustace.

Along the sea beach between Bray and Greystones, low cliffs of limestone boulder-clay may be seen, with a covering of sand and gravel, and loose stony Drift, with numerous fragments of local (granite and Silurian) rocks. At Bray Head the brown gravelly Drift is well shown.

In various places the limestone gravels are seen to be well stratified; at the southern end of the Glen of the Downs the horizontal layers of sand are "so cemented by foreign matter (probably calcite) as to project five or six inches from the surface of a section without breaking." Near Newtownmountkennedy the stratified gravels contain boulders of limestone, together with fragments of shale, quartz, and some chalk flints.

---

* Sheets 120; 121, 130; 129; 138, 139; 148, 149; 158, 159; 169, 170, 180, 181.

Near to, and south of Wicklow, a brown calcareous clay is occasionally to be met with, known as the Wexford marl. It contains chalk pebbles, and underlies the gravelly limestone Drift of the locality, as at Blainroe.

A thick deposit of granitic detritus and boulders covers the whole region about Lough Bray. The boulders decrease in size as the ground recedes from the granite area. Such granitic detritus covers the ground between the granite and Carrick Mountain, rising to an elevation of 1,150 feet at Moneystown Hill.

Eastward of Baltinglass the limestone gravels are found along the river valleys, up to a height of 700 feet, over which, in many places, are to be seen deposits of clay, which have been described as patches of Upper Boulder-clay. In the Derreen River, four miles west of Aughavannagh, more than twenty feet of plastic clay covers the gravels; and, along the course of the river, patches of sandy clay are seen, with blocks of slate and granite.

North of the River Slaney, limestone boulders are numerous in the Drift, and are burned for lime. North of Freynestown occurs a white tenacious calcareous clay which was formerly used as a manure.

About Ballitore and Timolin the Drifts are, for the most part, a clayey loam with limestones, sandy clay with slate debris, and a little limestone gravel.

South of Timolin occurs a coarse unstratified gravel, clay and sandy silt, with land shells, sometimes cemented into a conglomerate; and, around Baltinglass, the Drift contains limestone gravel with debris of greenstone, granite, and mica-schist.

The low-lying tracts bordering the coast about Arklow, are overspread by the Wexford "marl" above referred to, which is a boulder-clay, with sands and gravels; or by "shell marl," which is believed to represent Upper Boulder-clay, and has been much prized for agricultural purposes.

West of the elevated district which stretches southward by Shillelagh, the ground is covered with gravelly deposits more or less clayey, and usually stratified, which contain pebbles of limestone, grit, granite and trap rocks. These deposits were found up to a height of 900 feet in this district.

Limestone gravels seem to prevail over the area southward, except over some hilly districts in the region lying between the valley of the Slaney and the sea, about Enniscorthy. It is probable, however, that the Drift covering a great deal of the country west of that river, to the flanks of the Blackstairs Mountain, is of local origin. Terraces and banks along the Slaney valley are formed chiefly of "marl" and "manure gravels," while Drift above 300 feet elevation is of local origin.

In proceeding southward along the coast, beds of sand appear in the "marls"; and sections showing this are followed by others up to seventy feet in height, in which sand and marl appear in alternating layers. The sections are replaced still further south by those showing only gravelly Drift with clay.

These conditions of the Drifts prevail inland up to a height of between 200 and 300 feet; and the deposit is found to contain Arctic and other shells, chalk-flints, pebbles of hard chalk, jasper and coal, and magnetic-iron sand. These stratified deposits have been attributed to glacio-marine agencies; but more probably they were deposited by floods from melting land-ice.

Much of the region around Mount Leinster shows Drift which is probably of local origin, and representative of Upper Boulder-clay.

The whole southern part of Wexford is overspread with Drifts, the varieties met with being those above described as manure-gravel, shelly sands, marl, and clay—often a good brick-clay—in the ground lying below the 300 feet contour; while the higher grounds are largely covered with local Drift.

Along the south coast, at and east of Bannow, a number of Drift sections are to be observed. These usually present sand and gravel, often rendered conglomerate-like by infiltered substances. The sands and gravels are covered with a clayey gravelly Drift. Glaciated boulders are to be met with in the "marl," and chalk flints notably occur in the shelly Drift here—larger and more numerous in Wexford than they are even in Wicklow, Dublin, and Louth. This fact has led to the suggestion that they have been transported from an eastern source rather than from Antrim; but such an origin is improbable.

The following note is transcribed from the Memoir of Sheet 169, p. 53, viz.:—"The marl and shelly sands (manure gravels) were also extensively used as fertilizers, but, greatly to the loss of the community, their use was discontinued . . . now they are very little used."

Moraine-Drift.

Some remarkable assemblages of granite blocks are to be observed in the higher portions of the valleys which furrow the Leinster range. Two of these may especially be referred to, those, namely, connected with, and forming part of, the moraines which dam the waters of Loughs Bray and Nahanagan. The blocks of granite are commonly of immense size, and extend some distance down the valleys through which the waters of the lakes flow. These moraines have been described by Professor Hull* and Rev. Maxwell Close.†

Another pile of granite blocks is to be seen on the east side of the Avoca River, in the townland of Cherrymount, eight miles from the granite area; and close to Ashford is an assemblage of granite and greenstone blocks, ten miles distant from the granite area, which probably marks the most eastern limit for granite Drift, at least approximately.

On the north and west side of Mount Leinster moraines also occur; much of the Clady River valley is occupied by a terminal moraine, full of very large blocks of granite.

Brick-clay is found near Bray, Arklow, Rathnew, and Ashford.

DISTRICT 4.‡—South-western portion of Leinster, to the south of District 2, and west of District 3.

The region lying to the south of Parsonstown and Maryborough, generally, is overspread with Drifts, the higher portions of the hills, and small areas only of the low ground, being devoid of them. They are to be found to a height of 900 feet in many of the mountain glens, wherein they lie 100 feet thick in certain places. in Glenbarrow, on the north side of Slieve Bloom, they reach 1,300 feet elevation. The deposits contain much limestone detritus even to a considerable elevation in the glens; and in the lowest parts consist often of limestone boulder-clay or limestone gravels. In the uppermost parts the deposit is largely formed of local Drift, in which limestone fragments are rare.

The chief portion of the Drift of this region must have travelled from the north-west, inasmuch as boulders and fragments of Galway granite are of frequent occurrence therein. One of the granite blocks found on the *south-eastern* slopes of Slieve Bloom measured ten feet, by five, by three.

A great deal of the Drift covering the Old Red Sandstone, which flanks the Slieve Bloom hills, is of local character, being chiefly Old Red Sandstone debris, and is often of considerable thickness. At Bennett's Bridge, four miles W.N.W. of Mountrath, the river cuts through fifty feet of Drift, the lower thirty feet of which is brownish clay, with sandstone and limestone blocks; while the upper twenty feet consists of stratified sand, with curious calcareous concretions.

Limestone Drift is prevalent over the region where Queen's

---

* "Physical Geology of Ireland," 2nd ed., pp. 133 and 228.
† J.R.G.S.I., Vol. V., Part I.
‡ Sheets 126; 127; 128; 136; 137; 146; 147, 157 ; 156; 168.

County, Kildare, Carlow, and Kilkenny adjoin, and reaches to 1,000 feet elevation. The tops of some of the Coal Measure hills, and portions of the table lands lower than 1,000 feet, are devoid of it. The average height at which the deposit occurs is from 325 to 500 feet, above which there is only local detritus of the Coal Measures. On the falling ground, eastward towards Castledermot, much of the Drift consists of sands and gravels, portions of which are cemented into the form of conglomerate. The limestone Drift also extends over the granite area eastward of Carlow.

A three-fold division of the Drifts has been noticed in the region here referred to, and described in a second edition of Sheet 127, thus:—

The Lower Boulder-clay is a tough hard clay, with angular pieces of limestone polished and striated. The surface is often deeply eroded, and above it are the stratified sands and gravels, with occasional beds of clay. The Upper Boulder-clay is seen in some localities resting upon the denuded surfaces of sand and gravel or on a surface of boulder-clay. An example may be seen near Kilkenny. Illustrative sketches have already been given (pages 138, 139), showing cemented gravels capped by Upper Boulder-clay, as seen in the Dinan River-bank, south of Jenkinstown demesne; and showing the relations of the Drift members as seen at Erindale, near Carlow, and at Coonbeg, in Queen's County. The three divisions were also recognised in the engine pit of the Moderbeagh Colliery, near Wolfhill; and the Upper Boulder-clay was found to have a thickness of eighty-four feet. At Newtown Colliery the following remarkable section was exposed:—

	Feet.
Drift, ...	96
Peat, ...	3
Drift, ...	9
Total thickness, ...	108

The peat here mentioned was highly bituminous, and blazed like a candle.

In another pit the following section was seen:—

	ft.	in.
Clay, with boulders of limestone, ...	36	6
Sand and gravel, ...	6	3
Calcareous "book clay," or "leaf clay,"* ...	3	2
Strong clay, with detached pieces of coal, ...	6	0
Fine sand, ...	4	0
Total, ...	55	11

---

* Thinly laminated clay.

In the region lying around and to the south of Kilkenny, the Coal Measure tract is comparatively free from Drift. The low grounds are generally covered with limestone gravels, while on the hill flanks, where limestone Drift is to be seen, it is more clayey, and contains locally-derived pieces of sandstone and grit. The deposit varies in thickness from a foot or two up to 100 feet—sections from 20 to 40 feet in height are to be seen along the Mansler river.

Generally the Drift partakes of a character corresponding to that of local rock debris, containing pebbles of grit and shale over the Coal Measure ground, Old Red Sandstone blocks over this Formation, limestone fragments over the limestone area, and those of granite over the granite area. There is, as might be expected, also a mingling of such materials. Coal Measure debris is found over the limestone plain, generally resting upon limestone gravels.

Limestone Drift occurs sparingly in the valley of the Nore, below Graiguenamanagh; a small patch is to be seen at St. Mullins. It is, however, again to be met with in the valley through which the Waterford Railway runs; the sand here is full of limestone pebbles and the Drift rises to a height of 700 feet on the Old Red Sandstone hills. The limestone Drift occurs at a height of 700 feet over the Silurian area on the Nine-mile-house tableland; it now remains isolated from the corresponding deposit, which rests upon and ascends the flanks of the tableland, to 600 feet on the north side and 450 feet on the south. The Drifts here are of two kinds, viz.—brown gravelly clay, which is calcareous, and contains numerous pebbles and well-rounded boulders of limestone; and sand and gravel, with well-rounded pebbles and boulders of the same rock. Where these two varieties occur together the clayey Drift is found below the other.

Eskers.—A well-defined ridge extends in a northerly direction from Sheffield House, two miles south of Maryborough, to Mountmellick. Good sections of this ridge, showing the layers of sand and gravel that have been very irregularly deposited, are to be seen north-east of the former town. Over the Silurian ground on the slopes of Slieve Bloom, near Grahan Castle, much Esker Drift occurs, with reddish sand, containing blocks of sandstone and limestone, or coarse gravel, with grit and limestone fragments. A remarkable esker extends from Stradbally, for three miles to the south-west, near Timahoe, where it divides into irregular ridges to south-west and north-west; the latter terminates in the hill called Brockna, which occupies a space of fourteen acres.

East of Bagnalstown occurs an Esker consisting chiefly of limestone gravel and sand, though resting upon granite. It extends for over three miles from the vicinity of the town in a south-easterly direction, with a height above the surrounding plain of 40 to 50 feet. Several other small eskers have been met with in this district, none of which demand special notice here.

Economic Clays.—A deposit of pipe-clay which was once worked, occurs on a hill-top near Black Bull, four miles N.N.E. of Shinrone. It was said to be 20 feet deep, and appears to lie on the rock, probably beneath Drift.

In the valley of the Barrow are clays which were used for brick and tile-making. They occur in pockets of the Drift, and it is remarkable that these clays are seldom calcareous.

Brick-clay is also found at Athy, Grague near Carlow, Durrow, and on the tableland south of Stradbally; and it has been utilized for tile-making near Luggacurren.

CHAPTER XVIII.—MUNSTER.

Throughout West and South Munster, the soils, even where they are formed of drift materials, are usually such as would be derived in place from local rock-representatives of the Carboniferous and Old Red Sandstone Formations. A notable exception is the soil at the head of Bantry Bay. This derives much of its value from limestone boulder-clay which occurs in that region. The enrichment of the soil by this valuable material is modified by a covering, upon the boulder-clay, of locally derived material of less value; yet the verdure which clothes these deposits stands in marked contrast to the barren appearance presented by the country at some distance from the bay. Similar enhancement of agricultural value accompanies the occurrence of limestone detritus in many places amongst the Silurian hills of Tipperary and Kilkenny, where, as at Bantry, the same remarkable arrangement of materials is noticeable, viz. :—a thick deposit of limestone Drift, between Silurian grit and slate below, and debris of similar grit and slate above. The latter in most cases forms the soil, where the limestone Drift is present; while this forms only the deeper subsoil. The soils of the Golden Vale consist for the most part of mixed materials in which intermingles a large proportion of local limestone detritus.

DISTRICT 1.*—North-western Munster, extending southward to Dingle Bay, Castleisland, and Newmarket; and eastward to the meridian through Ennis.

The northern part of this District presents a great extent of bare limestone rock, which forms the peculiar tabular features of the Burren region. Drift has accumulated in the valleys, and consists chiefly of limestone detritus, though it also contains pebbles and blocks of South Galway granite. These are particularly numerous in the Ballyvaughan valley. Over the Coal Measure ground, to the north and north-east of Liscanor, blocks of limestone occur in the boulder-clay, and are utilized for burning. West of Ennis, also in the Coal Measure area, limestone gravel or clay, with limestone boulders, is distributed in such a manner as to suggest a former wider extension of these deposits.

Drift, derived from the local Coal Measure strata, and consisting of sandstone and shale detritus, covers much of the ground on both sides of the Shannon, near Kilrush and Tarbert. It contains, however, fragments of limestone and granitic rocks. In the eastern part of the barony of Clonderlaw, limestone debris increases in proportionate quantity towards the limestone area; and on the south side of the estuary, limestone gravels are frequently to be met with in the vicinity of Foynes and Glin, where the Drift also contains fragments of grit and granite, and of other igneous rocks.

---

* Sheets 114, 122, 123; 131, 132; 140, 141; 142; 150, 151; 152; 160, 161, 171, 172; 162 163.

A Drift-covering prevails in North Kerry over all except the higher portions of the ground. It is usually of local origin, containing grit and shale fragments in the central parts; it consists of limestone debris about Listowel and around Tralee Bay, where it resembles the limestone gravels of other parts of the country; and in the eastern parts of the region mentioned—North Kerry—limestone Drift is of common occurrence over the grits and shale of the Coal Measures.

Limestone blocks in the valley-Drifts are numerous, and in times of flood they are frequently washed down to the plains, and used for making lime. Blocks are found in the valley of the Finglass brook up to 500 feet above the sea, and four miles distant from the limestone area.

In the vicinity of Castleisland, Tralee, and Ardfert the Drift is generally confined to the limestone districts. On the lower slopes of Slieve Mish, Old Red Sandstone debris mingles with that of limestone to form the Drift. Near Kerry Head limestone blocks were observed in the deposit which covers, and is largely derived from, the local Old Red Sandstone strata; though the blocks are at least six miles distant from and westward of limestone *in situ*.

Deposits of sand occur in the townlands of Oorla, east of Foynes, and Tiermore, two miles south-east of Shanagolden.

Moraines.—On the eastern side of Lough Cruttia, under Brandon Peak, are mounds of coarse angular detritus at a height of 800 feet, obviously of moraine origin. Glaciation was observed in this neighbourhood up to 1,300 feet.

In the glens of Derrymore and Curraheen, moraine mounds also occur, which, in certain places, have quite an artificial look. On the northern flanks of Slieve Mish range, near Tralee, at the mouths of the glens, are mounds of Old Red Sandstone blocks, and other accumulations of local origin which are believed to be moraines.

Economic Clays.—A stiff whitish clay, from which fairly good bricks are made, is in some places found over the limestone Drifts, and a calcareous shelly deposit—marl—was noticed at Licknaun and Cloonteen Loughs. Brick-clay also occurs in the tract bordering the River Fergus; as well as at Listowel, Tralee, and near Newcastle West.

DISTRICT 2.*—North-eastern Munster, extending westward to District 1, and southward to a line passing through Doneraile and Carrick-on-Suir.

---

* Sheets 124, 125; 126; 133; 134; 135; 143; 144; 145; 146; 153; 154; 155; 156; 164; 165; 166.

In East Clare, the low ground—roughly corresponding in outline with the limestone area in the region—is generally overspread with Drifts, which for the most part consist of limestone gravel and boulder-clay. The slopes of the hills usually bear a covering of Old Red Sandstone detritus, with fragments of Silurian rock intermingled; and Drift of this character spreads outward from the hills over the limestone area at their foot.

On the southern parts of the hilly ground around Broadford, perched blocks of limestone occur, and boulders of the same kind are of frequent occurrence in the lower portions of the locally-derived Drift, which covers the Old Red Sandstone tract, west of Killaloe.

North-west of Tulla, reddish brown clay contains angular blocks of red and yellow sandstone; and about Spancilhill, to the north-east of Ennis, similar materials mingle with debris of limestone, together with blocks of conglomerate.

As on the west side of the Shannon, the Drift on the eastern side largely consists of limestone gravels, with boulder-clay occasionally, over the lower ground. Amongst the hills of the Keeper group important deposits of locally derived Drift occur, especially over the Old Red Sandstone area, which forms the margin of the hilly tracts. Within the Silurian areas, thick accumulations are to be seen in various places, as in the wider valleys in the centre of the Keeper group, about Castle Otway. In many places, particularly in the lowermost portions of thick sections, limestone fragments mingle with the Drift, which almost wholly consists of Silurian debris; and it is not uncommon to find, along the main valleys. that such Drift conceals deposits of limestone till, of greater or less thickness, containing polished and scratched blocks of limestone and Galway granite; and this even where blocks or fragments of Old Red Sandstone are comparatively rare or wanting in both the upper and lower Drift. Stratified limestone sand and gravel occur well within the Silurian area in Lateragh Valley, and the gravel is in parts cemented into a conglomerate.

The limestone Drift is found on these hills at considerable elevations—up to 600 feet in some places; and near Moneygall and Toomyvara erratics of granite and limestone are scattered over the flanks up to a height of 890 feet above the sea-level.

West of the Maigue river, in Limerick, not much Drift is to be seen; that which exists there is thin and of a local character. East of that river, however, the ground is usually covered with Drifts, which consists of limestone gravel and boulder-clay, often of considerable depth, and contains fragments of Galway granite rocks.

The extensive low-lying area extending eastward from Rathkeale by Tipperary to Clonmel, is generally covered with Drifts, which in many places are deep. The deposits consist chiefly of limestone gravel, with variable quantities of clay; and contain numerous boulders of limestone, sandstone, and other varieties of rock, including those of igneous origin.

At, and south-westward of Galbally, extending over part of the Silurian area, occurs a clayey gravel with blocks of limestone. Local Drift of a red colour clothes the sides of the Glen of Aherlow; the fragments of sandstone are not usually rounded, and only a small proportion of limestone pieces intermingle therewith. Boulders of Galway rocks, granite and (?) syenite, are found as far south as the region of the Galtees, though even this seems not to be the most southern limit to which the dispersion of these boulders extends.

The limestone Drift, which covers the limestone area near Charleville, spreads also over the Coal Measures in the vicinity, though the prevailing Drift is of local origin; it also occurs around Doneraile, Buttevant, Churchtown, and Liscarrol; and, spreading over the Mitchelstown limestone tract, it ascends the Knockmealdown hills to a height of 400 feet, though it is not found up to a corresponding height upon the opposite side of the valley—the southern slopes of the Galtees. This fact points to a southward movement of the transporting agent. Eastward, in the region of Cahir and Clonmel, the limestone Drift extends up many of the valleys to heights of 750 feet above the sea—500 feet above the plain; it is, however, much mixed with locally-derived debris.

Eskers, Sands, &c.—South of Cratloe Wood, west of the Shannon, occurs a deposit of fine rabbit sand, which is fifty feet thick in some places. On the east bank of the river, near Bird Hill, west of the Slieve Phelim hills, and at several points in the Golden Vale, stratified sands and gravels are to be found forming hillocks and low mounds, which represent Esker Drift. The only striking ridge noticed in this region is one to the southward of O'Brien's-bridge.

Economic Clays.—Deposits of pipe-clay were reported to occur in the townlands of Knockgraffon and Mooretown in the district of Cashel. In Loughlokery and Ballymacadam, south-east of Cahir, pipe-clay has been found with lignite. In the latter place, the lignite of a rich brown colour exists under a depth, it was said, of 15 feet of pipe-clay. The pipe-clay is white or pale gray, very tenacious, and the part over the lignite is full of black specks; while below, it is pure, and said to have been manufactured into articles for table use.*

Potters' clay occurs at Killenaule; and Brick-clay at Limerick, Nenagh, Clonmel, and near Thurles.

---

* Paper by Sir R. Griffith, *Trans. Roy. Dublin Soc.* Also Paper by Mr. Wynne. *Proc. of the Brit. Assoc.*, 1857

District 3.[*]—Southern Munster, extending northward as far as the boundaries of Districts 1 and 2.

In the south-western part of Kerry, small areas of Drift are to to be met with—accumulations of moraine matter amongst the gaps and valleys which traverse the Macgillicuddy Reeks, and the promonotories which extend south-westward towards the ocean; also irregular deposits of boulder-clay and gravels, which dot the low-lying grounds adjoining the much-indented coast line. The southern portion of the Kerry Coal Measure area appears in the northern portion of the present District; and the plateau which forms this included portion, as well as the southern flanks of the Tralee hills, are covered with Drift which is locally derived.

The lower-lying portions of the hilly tracts are also covered with local Drift; but, along the coast line, this contains materials drawn from the Coal Measure strata, a good distance to the north-east; and boulders of limestone, probably washed out of the Drift, are scattered along the beach at the foot of Knockatinny and Knockboy.

At Ballinskelligs Bay a section was observed (a sketch of which is here given, Fig. 61),[†] which shows twelve feet in depth of boulder-clay (A), resting upon obliquely stratified sand and gravel (B).[‡] The

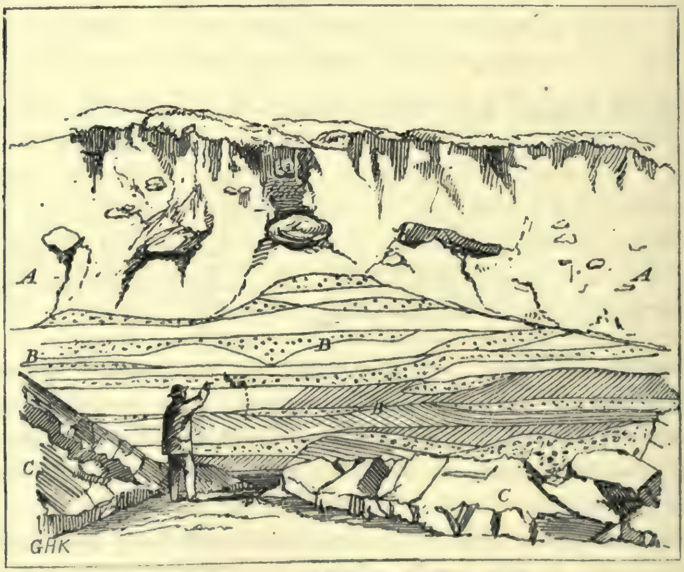


Fig. 61. Section of Drift, Ballinskelligs Bay.

---

[*] Sheets 172; 173; 174: 175; 176, 177; 167, 178, 179; 182, 183, 190, 191; 184; 185, 186; 187, 195, 196; 188, 189; 192; 193; 194, 201, 202; 191; 197. 198, 191; 199, 200, 203, 204, 205.

[†] From Explanation of Sheets 182, 183, 190, p. 32

[‡] Sections 38 feet in height occur near the point at which the sketch was taken.

latter are converted into recent conglomerate at this place. Sections are also to be observed at Waterville, on Scariff Island, and on the west side of Rossdohan Island to the south of Sneem. In the last section the Drift is seen to be nearly 120 feet in thickness, and to be the remnant of a local mound, left by erosion.

Eastward from Killarney the ground which lies at the base of the mountains is covered with a thick accumulation of very coarse boulder-drift. North of Lough Guitane the Drift consists entirely of well-rounded grits and sandstone, bedded in sand and gravel, and has evidently been derived from the Old Red Sandstone strata which form the neighbouring hills. Though the Drift spreads over the Carboniferous limestone of the valley, it is practically devoid of fragments of that rock.

At the foot of Caherbarnagh, and towards Millstreet, eastward, materials drawn from the Coal Measure strata on the north, mingle with those derived from the Old Red Sandstone, to form the Drifts; and fragments of limestone have been reported as occurring in this locality.

Locally formed Drift is distributed over much of the high ground north of Macroom, reaching an elevation of 2,050 feet in Mullaghannish Mount, in the Bochragh range. Notwithstanding this, many rocky eminences and ridges little over 1,000 feet on the southern side of that high ground are quite devoid of Drifts.

In the extreme south-west of Cork the country in general is singularly free from Drifts, though patches occur sometimes on the flanks of the hills, up to a height of 600 feet above the sea, with a depth of thirty or forty feet occasionally, along the sea shore at intervals, and also along the bottoms of the valleys. The rounded hills of Whiddy Island are composed of boulder-clay, as well as those about Reenydonagan and Gurteen Roe, and north of Bantry. Blocks of "crinoidal limestone, exactly like ordinary Carboniferous limestone," some of which are three or four feet across, not uncommonly occur in this Drift; and it is stated in the published Memoir of the District (Sheets 192 and 199) that "they have not been derived from any rocks now existing in Bantry Bay (region), or anywhere on the south side of the Glengarriff range of hills." This description refers to the lowest portion of the Drift; the uppermost, as already mentioned in this book, consists almost solely of local debris.

The ridges and roundish hills of Drift may be followed from Bantry, for six miles along the valley of the Melagh River upward, clearly distinguishable from the hills of rock by their smooth, regular forms, and their green cultivated sides, while the rocky hills are rough and dark, with heather and gorse. The Drift hills are isolated from each other, uncovered strata being often visible in the intervening spaces. They each stand upon a base of about half a mile in diameter, and are from 100 to 150 feet in height.

Numerous mounds, probably of moraine origin, dot the valleys in this region. They form specially prominent objects in the Pass of Cappanohola; along the northern slope of Knocknavea up to a height of 500 feet above the sea, and along the south side of Bantry Bay.

Judging from the distribution of the superficial deposits in the district, their occurrence in isolated patches, and their nature, it has been concluded, as stated in the Memoir, "that the whole country was once covered with a mass of Drift 50, 100, or 150 feet, . . . and that it has since been swept off the country, with the exception of the mounds and patches of it now described."

Erratic blocks are of frequent occurrence over this part of Cork; and the rocky surface throughout, shows evidence of intense glaciation. Sands and gravels are rarely to be found, though such deposits have been met with southward of Dunmanway, around the bogs and alluvial flats of this portion of the Bandon River valley. Locally formed Drift is also to be found in various places around and to the south of Bandon.

No limestone boulder-clay or gravel has been met with eastward of the barony of Bantry for many miles, for which reason indications of Drift are absent on the published one-inch maps of the region. The exceptional agricultural advantages attaching to limestone detritus, as well as the usually small depth of local Drift, led to the decision formerly acted on by the Survey Staff, to map only the areas covered with limestone Drift, or with local Drift, when present in considerable thickness.* Only such areas are represented by engraved dots on the earliest published geological maps of South and South-eastern Ireland.

Clayey Drift is to be seen at several points on the Glanworth side of the Blackwater valley, also at Glenfinish, three miles east of Kilworth, where it is twenty or thirty feet in thickness. A deposit of some depth covers a good deal of the low country near Rathcormack; and much clayey Drift is to be seen over the Old Red Sandstone north of Cork valley. This Drift is of local origin, though at one point several small rounded boulders of coarse-grained granite (probably from Leinster) lie scattered over the surface of the ground. Boulder-clay containing scattered boulders of limestone, over gravel and sand, itself also becoming gravelly in certain places, occurs in the low ground south of Cork.

---

* The following note by Professor Jukes, a former Director of the Geological Survey of Ireland is of interest:—"The limestone gravel, which spreads over so large a part of the centre of Ireland, extends also generally, but not with any great thickness, over the limestone plain of Castletownroche; but in the rest of the district (Sheets 176 and 177), although the rocks are often covered with superficial deposits of clay, sand, or gravel, these deposits are of such a purely local origin—possibly resulting from mere atmospheric action—that it was not thought advisable to indicate them by engraved dotting. That dotting is introduced only when the drift is so abundant as to greatly obscure the rocks below, and render their boundaries uncertain, or where it has an economic value, as when it consists largely of calcareous pebbles, and therefore raises the agricultural value of the land beyond that which it would possess if it were uncovered sandstone, or slate, or granite, or mere uncovered limestone; or if these rocks were covered by non-calcareous drift." Explan. of Sheets 176, 177, pp. 28, 29.—Footnote.

Sands and Gravels.

Stratified sands and gravels are to be seen at various points around Cork:—a considerable area north of the city; on the borders of the Lee, at Little Island, and near Midleton. The gravels consist almost wholly of well-rounded pebbles of local grit and sandstone. Very few fragments of limestone are to be met with therein, even where the deposits form large mounds thirty or forty feet high at Midleton, and rest upon limestone.

In the Castlemartyr valley the Drifts are represented by large deposits of clay and gravel. Towards the coast, between Cork Harbour and Youghal Bay, a deposit of calcareous mud and sand occurs, which contains chalk flints and shells.

Moraines.—Some striking accumulations of coarse angular debris, as well as promiscuous heaps of coarse gravel, and partially rounded blocks—all of moraine origin—are to be met with in the higher valleys of the District. One picturesque glen may especially be referred to—that traversing the Comeragh Mountains, between Loughs Coumgorra and Comeragh. It is no more than 1,000 feet in width, and a mile in length; and its mouth is spanned by a series of mounds which stand 1,400 or 1,500 feet above the sea.

Brick-clay occurs near Youghal, Ballinhassig, and Douglas; and at Ballinlee near Kinsale.

SECTION IV.

CLIMATE.

CHAPTER XIX.

Influence of the Irish Climate on Agriculture.

The earliest accounts of Ireland given by Strabo and other ancient writers, contain references to the unfavourable character of our climate. It was by them described as wet, windy, and cold; and modern visitants from countries bordering the Mediterranean, judging, like the others, from their own more favoured surroundings, would probably consider that no material climatic changes have taken place in our island to the present day. The lessening of water areas, and the drainage of bogs and swamps, have doubtless wrought a measure of amelioration. Yet the changes which have come about, through the long span of two thousand years, even where the works of man have, to a large extent, supplemented the operations of natural agencies, have failed to obliterate the characteristic and uninviting features of our climate, which may be described as fickleness and persistent humidity.

One of the greatest changes wrought by man in Ireland, and calculated to affect its climate, is the regretful clearing away of forests * which, even up to recent times, covered a large part of the island. While it may be a moot point, whether the existence of forests or their removal affects climate prejudicially or otherwise, there can be no doubt that they tend to affect evaporation† in regions which they cover, moisture being dispersed through the foliage rather than drawn altogether directly from the soil.

* Mr. Bailey, Irish Estates Commissioner, in his Papers in the "Journal of the Statistical and Social Society of Ireland." August, 1889, and July, 1890, called attention to the reckless clearing away of timber and peat likely to follow the sale of holdings to the tenants, through lack of sufficient protection of woods and bogs under the Land Acts. An instance has recently come under the present writer's notice, in which a landlord, through his agent, sent his men to cut down the saleable trees in one of the few woods to be seen in a specially bare part of the country, contrary to the tenants' protestations and offers of money to allow the trees to stand. Probably landlords have as much (or more) right to clear away timber before selling their properties, as tenants have to do so after purchasing; but it is perfectly clear that if either class exercise what they deem their *right*, it will be in disregard of a very definite public interest particularly in Ireland where, for shelter and landscape, woods are all too scarce.

† See Note at end for results of experiments upon evaporation from evergreen and deciduous trees (p. 277).

Effects of Vegetation on Climate.

The prolongation of evaporation in the way mentioned, and the consequent maintenance of a moist atmospheric envelope for a longer time, may tend to prevent such extremes of local heating and cooling, in both soils and atmosphere, as would obtain in the absence of forests. The reader will find a full discussion of this subject in Marsh's "Man in Nature" (pp. 133 *et seq.*), or in a new and enlarged edition of that work entitled "The Earth as Modified by Human Action." The author there gives instances of serious climatic and meteorological changes, attendant upon the wholesale felling or destruction of forests,* such as increased frequency and violence of hail storms in the Riviera and other districts in northern Italy, and disastrous visitations of late frosts in Ardèche and in countries north of the Alps. Owing to this, fruit trees no longer thrive, and it is difficult to raise young trees. In the Cevennes also, the prevalence of the Mistral, or north-west wind, the chilling blast of which is so destructive of tender vegetation in late spring, has been ascribed to the same fatal cause.

Seasonal Modifications.

It would, therefore, seem fairly inferable that, though no great *average* changes may result to a country, from the removal or raising of forests, seasonal and local changes may be wrought; and it is precisely upon such changes that the promotion of vegetative and maturing processes in crops, or the contrary, depend. Amongst the benefits that would attend re-afforestation, not the least is the shelter which woods afford; and this should be particularly worthy of appreciation in Ireland, where stock-feeding in the open is so much practised, even in winter.

Mr. John Knox Loughton, M.A., F.R.A.S., states†:—Mean temperature gives little or no idea of climate, or of the forms of vegetable or animal life, for which it is fitted. The mean temperature of the Hebrides is the same as that of the north shore of the Caspian, or sea of Aral. As against an intense cold of the eastern winter, there is the summer of great brilliancy and warmth. 'Corn is sown, springs up, ears, and ripens within a few weeks; and choice vines, apricots, peaches, or mulberries, with a very moderate amount of care, bear fruit abundantly.' . . 'In the Hebrides, where snow seldom lies for twenty-four hours . . . ., corn ripens only in exceptional years, and fruit of any kind is almost an impossibility.'

---

* It has long been recognised that forests on hillsides prevent excessive erosion of the soil in such situations, and that their removal has sometimes ruined the agricultural productiveness of a district.—See "Text Book of Geology," by Sir A. Geikie, LL.D., F.R.S.

† "Modern Meteorology," p. 54.

Influence upon Stock and Tillage.

The unfavourable characteristics of our climate do not militate seriously against the general healthfulness of the country. In the important matter of stock-farming also, they appear to be innocuous; indeed the usual mildness* of the climate in winter is highly favourable to this branch of the agricultural industry. The superior quality of Irish-bred hunting and steeplechase horses, moreover, is probably in measure attributable to our climatic conditions. In such respects, therefore, the conditions are rather advantageous than otherwise.

On the other hand, *humidity* is highly unfavourable to crop-raising, as is *fickleness* to the saving of several of our agricultural products; and the constant drenching of the soils, as in the wetter portions of the country, deprives them of valuable fertilizing ingredients. It is not that the rainfall throughout is excessive. At no point in Ireland has there been so great an annual rainfall recorded as at Stye, in Cumberland, where it has amounted to 224½ inches. What is so objectionable and sometimes disastrous, as Arthur Young long ago pointed out, is the constant moisture, which frequently occasions late seed-time, slowly-ripening and ill-conditioned cereals, and late harvests; with the usual accompaniments of early potato-blight and mildew.

The main cause of Ireland's humidity is its exposure to moisture-laden winds from the Atlantic. By far the most prevalent† throughout the year are those from the west and south-west. These are moist winds, and affect Ireland in a special way, it being the first land met with in their progress eastward. They affect the British Isles more than the contiguous parts of Europe; Ireland more than central England; and the south-western part of our country more than the north-eastern. Again, winds blowing from the south, also charged with moisture, bear particularly upon Ireland, standing as it does upon the western limit of the European border.

Climate and Weather.

One of the characteristics of our climate is, therefore, seen to be a concomitant of the geographical situation of the island. The effects of humidity, however, are not experienced equally throughout.

---

* Mr. M'Connell, in his well-known and valuable "Agricultural Notebook," points out that while the January average mean temperature at points along the east coast of Britain is 37° F., and along the west coast 39° F., the January average for south-west Ireland is 45° F.

† It is recognised that east winds which blow over a great extent of European lands, and are therefore practically dry winds, generally prevail in spring; but, taking the year as a whole, east and north-east winds are amongst the least prevalent.

They are more felt in mountainous districts than over the central plain; moisture—rather the condensation of vapour, like rainfall—is governed to some extent by surface configuration. These circumstances, and the character of our seasons, go to make up what we call *climate*. It is difficult to differentiate therefrom the circumstances which govern or constitute *weather*, though generally we connect with the latter term, elements of variability and fickleness which are chiefly dependent upon the changeableness of wind-directions. We may conveniently consider the circumstances, in so far as they affect Ireland, and the simple physical principles involved—their mutual relations and bearings—by grouping them under the following heads, viz.:—

- Temperature.
    - Latitude.
    - The Gulf Stream.
    - Configuration of the Ground.
    - Aspect.
    - Relation of Temperatures of Air and Soil.
- Aërial Currents.
- Atmospheric Moisture.
- Vapour Condensation.
- Cloud, Fog, Dew, Mist, Rain.
- Wet and Dry Winds.
- Rainfall.
- Weather Prognostication.

TEMPERATURE.

There are few who are not aware that an increase of temperature is experienced in descending mine-shafts. Hot springs also testify to the existence of more highly heated strata some distance downward in the crust than are found at the surface. It has been ascertained that, in general, for every 50 or 60 feet downward there is an increase of one degree Fahrenheit. Some distance from the surface, however, there occurs an invariable stratum, below which the temperature steadily rises; while above, seasonal and diurnal changes are noticeable. It will therefore be perceived that the internal heat of the earth cannot greatly, if at all, affect local temperatures in so small an area as that of Ireland. We may, therefore, ignore this consideration. Changes of temperature due to chemical and physical phenomena in the soil are noticable; but the causes from without are those with which we may be chiefly concerned here—they tend to regulate and modify the heat derived from the sun's rays; amongst them is *latitude*.

Difference due to Latitude.—The first obvious cause, to which variation of temperature throughout Ireland is attributable, is difference of latitude. It is a fact with which all are familiar, that the further north places are situated, in the northern hemisphere, the greater is the degree of cold. Exaggerated estimates of the difference of temperature on this ground, between the south and north of Ireland, will not, however, be entertained, when it is remembered that the length of our island from north to south is only about 270 miles, while the distance between the regions of tropical heat and arctic cold is about 3,000 miles.

The higher the sun is in the sky, the more effective is his heating power. The noon-altitude at any season of the year, say near Malin Head, is nearly four degrees less than at Cape Clear; hence a certain area of level country in the north, receives less heat than an equal area similarly situated in the south, and the atmosphere, heated by contact with the soil, should manifest a corresponding difference of temperature. A certain deficiency is also attributable to the difference in extent through which the sun's rays have to penetrate the atmospheric envelope.

The heat received by land during the day, disappears by radiation under a cloudless sky at night. Land, and the atmosphere in contact with it, may thus become cooled below freezing point. Cloudiness prevents radiation and hinders cooling; but it also hinders the heating effects of the sun's rays, which are in part intercepted and absorbed by atmospheric moisture.* The lower the sun is in the sky, the greater is the extent of the moist aerial envelope which its beams have to traverse; so that the proportionately small heating effect of the sun, when its rays strike the earth and the earth's envelope obliquely, is still further lessened by their increased interception and absorption. This lessened thermal effect is much more felt in Ireland in winter than in summer, because the sun's altitude is forty-seven degrees greater in midsummer than in midwinter.

The Gulf Stream.—A potent factor in modifying the climate of Ireland is the vast body of heated water known as the Gulf Stream, which laves our shores. It is part of the great Equatorial Current of the Atlantic, which enters the Gulf of Mexico, and issues therefrom with a greatly increased temperature, flowing by Florida and the coast of North America, and crossing the Atlantic in an E.N.E. direction. To the south-west of Ireland it divides into easterly and north-easterly branches, the latter being the more important. This flows towards the British Isles and past Ireland, still retaining a large proportion of its acquired heat.* Part of this branch of the current strikes the south-west coast of Ireland, and flows northward. Part of the easterly branch also is deflected northward from the Bay of Biscay, and strikes the Irish coast, as well as entering the St. George's and English Channels. The amount of caloric which the Gulf Stream retains and imparts to the atmosphere of the British region may be judged from observations given by M. Marié Davy,† as recorded by Captain Duchesne, in crossing the Atlantic from New York to France in 1865.

---

* Water becomes heated, and cools, less rapidly than land: hence the interior of a country is subject to greater extremes of temperature than its margin. Frost and snow may, and often do, occur in central Ireland when there is none within a few miles of the sea.

TABLE SHOWING DIFFERENCES OF WATER AND AIR TEMPERATURES OVER THE ATLANTIC.

Day.	Hour.	N. Lat.	Air Temp.	Sea Temp.	Diff.
10th November, ...	9 a.m.	40° 10′	46°·4 F.	51°·8 F.	5°·4 F.
11th November, ...	4 a.m.	40° 16′	41°·0 F.	57°·2 F.	15°·2 F.
11th November, ...	8 p.m.	40° 23′	39°·2 F.	59°·0 F.	19°·8 F.
12th November, ...	9 a.m.	40° 56′	39°·2 F.	69°·8 F.	30°·6 F.
12th November, ...	noon.	41° 05′	41°·0 F.	69°·8 F.	28°·8 F.
			Average	difference	20°·1 F.

The heating effect which these currents must have, prepares us to realize that the mean winter temperature of Ireland is higher by some 20°F. than that of places between the same parallels of latitude in America and West Russia; and the proximity of so great a body of water, of comparatively uniform temperature, is also productive of such an effect, that the mean summer temperature of Ireland is some 5° F. to 10° F. lower than that of East Prussia. The combined effect of the factors mentioned, results in a difference between the north and south of Ireland of about 4°F. in January, 2°·7 in August, and 3°·3 for the year.‡ A comparison of the temperatures of the sea on the north-east and south-west sides of the British Islands, given by Sir J. W. Moore, shows that the temperatures at Cleggan in the County of Galway, and Valentia in Kerry, are about 10° F. on an average for the year, greater than those observed at Berwick, Frazerburgh, and Burntisland.

In Ireland, the influence of the Gulf Stream upon the west and south coasts, is stronger than upon the east and north; this is obvious in comparing the mean temperatures observed at stations approximately of the same latitude on the east and west coasts. The well-informed author of the "Guide to the Principles of Land Valuation," gives data from which the following has been prepared:—

---

* Sir J. W. Moore, M.D., in his work on "Meteorology, Practical and Applied" (p. 314), gives 65° F. as the average temperature of the current in the Atlantic.

† "Météorologic Génerale," p. 145.

‡ Mentioned in "A Guide to the Principles of Land Valuation," p. 104.

TABLE of MEAN TEMPERATURE.

WEST SIDE.				EAST SIDE.			
Place.	Jan.	Aug.	Year.	Place.	Jan.	Aug.	Year.
Killybegs, ...	43°·8	60°·7	50°·8	Donaghadee,	42°·8	58°·8	49°·6
Westport, ...	46·3	60·9	51·7	Dublin, ...	43·6	62·0	50·3
Kilrush, ...	44·2	60·8	50·9	Courtown, ...	43·3	60·7	50·3

A comparison of the figures in this Table, reveals the fact that the isothermal lines, in other words, the lines passing through places of equal mean temperature throughout Ireland, decline from the parallels of latitude, owing to the greater influence of the Gulf Stream on the west, than on the east coast.

Configuration.—Another condition which affects local temperature is the configuration of the land. So material is the influence of this condition that, in virtue of it—other things being equal—Sir R. Griffith thought it necessary, in making his valuation, to deduct one shilling in the pound sterling from rents for every 100 feet elevation over 300 feet.*

It has been calculated that the mean annual temperature in the region of the same isothermal, lessens one degree for every 250 feet † ascent in the latitude of Ireland. It will thus be seen that the combined effect of the different causes above mentioned, is to make the annual mean at the 500 feet contour line near Dublin, for example, the same as at the sea level near Buncrana; and similar illustrative instances might be multiplied indefinitely.

It is known that crops in "bottoms," in the valleys of hilly ground, are peculiarly liable to injury through frosts. The cause of this is, that still air, in contact with the hill sides becomes greatly cooled, and, becoming thus heavier, descends into the low ground to chill the tender vegetation in early spring. On windy nights, the injurious effect of frosts is not so much experienced, because the air does not lie sufficiently long on the hill slopes to be greatly cooled; nor is it sufficiently steady to *flow* down the slopes into the valleys below.

---

* "Instructions to Valuators and Surveyors," pp. 35–38.

† Mr. R. H. Scott, in his "Elementary Meteorology," gives one degree for every 183 feet in perfectly *dry air*—a condition never realised in our climate. Others give 300 feet. The 250 feet given above is an approximate figure arrived at by dividing the difference in degrees between the mean annual temperature and 32° F. into the height expressed in feet at which the snow line, or plane, is supposed to pass above us, something less than 5,000 feet in our latitude.

Aspect.—This is a circumstance in configuration which considerably affects local temperature. It is almost needless to explain, that by aspect is meant the direction in which sloping ground inclines. A slope facing southward, that is towards the midday sun, receives his rays more directly, and, therefore, in greater power, than does a slope facing northward. It also receives light and heat for a longer time each day. A westward slope, moreover, is preferable to an eastward slope; for, upon the latter, plants frosted at night in spring, are liable to injury through being suddenly warmed by the early sun; whereas on the westward slope they are shaded till the frost disappears, and enjoy prolonged sunshine in the afternoon, when they can best profit by it. The circumstances of aspect explain why it is, that in the cases of many hills and some mountain ranges in Ireland, cultivation has been carried to a greater height on the south than on the north sides.

In a climate so damp as ours, sunlight and heat are liable to be much obscured and intercepted, particularly in the winter half of the year, when the sun is low in the heavens in the latitude of Ireland. It is of utmost importance, therefore, during germinating time in early spring, that his beams should be utilized to the full—gathered up or concentrated, so to speak—where possible. This is done by the selection, for early crops, of slopes with a southern aspect. At the spring equinox the sun has an altitude of about thirty-six degrees at noon in central Ireland*; at that time of day, therefore, each acre of level ground catches only about eight-elevenths of the amount of heat which an acre on a slope of fifteen degrees (about one in four) receives, if the slope have a southern aspect. An acre on a similar slope with a northern aspect receives only nine-twentieths of the amount.

Put in another way, with the aid of an illustration—suppose equal parallel beams of sunlight (and heat)—say 100 yards square in section—to fall upon the hills represented in Fig. 62, the strong lines forming the front margins of the clear spaces in the illustration will indicate the inversely proportionate heating power of the beams. The equal beams, in the three positions, will distribute heat over 5 acres 2½ roods, 3 acres 2 roods, and 2 acres 2 roods, respectively, following the beams in order from right to left in the figure. Professor King found * a very noticeable difference between stiff red clay on ground sloping at eighteen degrees towards the south, and the same kind of clay on the level.

---

* To be quite exact, the latitude of Cavan and Dundalk.

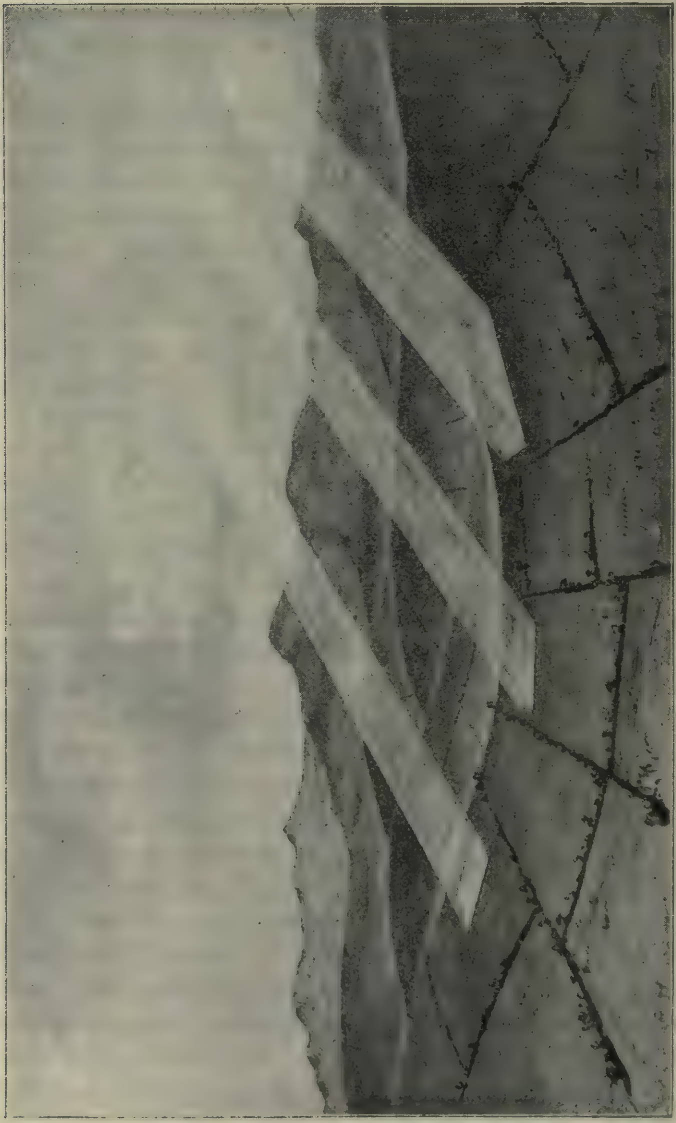


Fig. 62. Imaginary view to illustrate the difference caused by aspect, in the heating power of equal sunbeams.

---

* "The Soil," p. 228.

The difference is set forth in the Table, the temperatures having been taken on July 31, on the south shore of Lake Superior.

——	1st Foot	2nd Foot.	3rd Foot.
Red clay (south slope), ...	70°·3 F.	68°·1 F.	66°·4 F.
„ level, ...	67°·2 F.	65°·4 F.	63°·6 F.
Difference, ...	3°·1	2°·7	2°·8

Commenting on Wollny's researches on the influence of aspect, carried out on artificially formed hills with inclinations of fifteen degrees and thirty degrees, the same author states,* that the south side was found to have an average temperature of 1·5 degrees F. warmer, when the slope was fifteen degrees, and 3·1 degrees F. warmer with a slope of thirty degrees, than the north side; but comparing the east with the west slope, Wollny found less than 0·2 degrees F. difference.

Relation of Temperatures of Air and Soil.—There is little doubt that climate is affected, locally at least, and in some degree generally also, by the nature of soils and geological formations, as represented by Sir J. W. Moore, M.D.† Wet, marshy land, retentive and badly-drained soils, and boulder-clays, have a chilling effect upon the air above them; with the frequently attendant result of sheets of fog overhanging badly drained tracts, to various heights, and often of wide extensions. Formations of shale, clay, slate, &c., have the same effect, as compared at least with those of limestone and sandstone, which afford facilities for the escape of water; while areas of sand and gravel command a bracing local climate. Professor Seeley, F.R.S., classifies rocks and superficial deposits (sands, gravels, &c.), as follows, according to the effects they severally have upon local climate, viz.:—

Pebble beds, sands, . . .	Dry, bracing atmosphere.
Limestone, ...	Though usually well drained, is overhung by steamy atmosphere in summer.
Clay-slates, ...	Damp and cool atmosphere.
Crystalline rocks, . . .	Do., do.

Amongst the many valuable experiments carried out by Schübler some sixty years ago, were those with a view to ascertaining the relation of the temperature of the soil to that of the air. These observations were made throughout the course of two years at

---

* "The Soil," p. 229.

† *Op. cit*, p. 351, &c.

Tübingen, in Germany, the mid-day temperature being noted on perfectly fine days only, the thermometers having been set, one in the shade, and another with the bulb hidden in garden soil, just one-twelfth of an inch below the surface. A Table, as given by Warington,* indicates the results of the experiments; in which are also shown readings of thermometers observed at Geneva by Schübler in variable weather.

MEAN TEMPERATURES of SOIL and AIR at MIDDAY (Schübler).

—	In fine weather at Tübingen.			In variable weather at Geneva.		
	Surface Soil.	Air in Shade.	Soil in excess of Air.	Surface Soil.	Three inches deep.	Air in Shade.
	°	°	°	°	°	°
January, ...	54·1 F.	24·6 F.	29·5 F.	43·0 F.	38·5 F.	38·2 F.
February, ...	86·2	43·0	43·2	45·7	39·8	36·8
March, ...	99·5	46·6	52·9	53·2	43·2	38·1
April, ...	121·6	61·7	59·9	78·9	60·7	50·1
May, ...	131·2	67·3	63·9	80·1	64·4	55·9
June, ...	139·8	75·2	64·6	89·1	73·6	60·9
July, ...	146·3	81·3	65·0	93·4	73·3	63·2
August, ...	130·1	68·9	61·2	96·0	76·9	65·8
September, ...	119·8	68·0	51·8	82·8	70·2	62·4
October, ...	80·8	42·8	38·0	59·8	54·4	51·8
November, ...	72·7	40·1	32·6	47·3	43·7	41·6
December, ...	59·2	35·6	23·6	35·3	33·3	32·1

Even peaty or moory soils possess a degree of heat which they too impart to the atmosphere. It is well known that this heat may be increased by drainage, as well as by topdressing and other treatment. It is shown in an elaborate series of experiments conducted by Wollny at Munich in 1890, 1892, and 1893.† The experiments were carried out to ascertain the temperatures of lowland peat soils (*Niederungsmoorsboden*), and upland peat soils (*Hochmoorsboden*), as compared with that of the air—when topdressed with sand, and when the sand was mingled with the uppermost layer of peat. The sand was coarse-grained and siliceous, placed in layers of one, two, three, and four inches in depth, or mingled as described. The thermometers were set six, eight, or ten inches below the surface; readings were taken at 7 o'clock a.m., and at 5 o'clock p.m., every day during the season of active vegetation—1st April to 30th September—and from these the averages were found. The air temperatures were taken from observations at the Central Meteorological Station of Munich. "Variations in temperature" were the average differences (here converted into Fahrenheit degrees) observed between the highest and lowest daily readings.

---

* "Physical Properties of the Soil," p. 157.

† *Forschungen a.d. Geb. d. Agrikulturphysik. for* 1894, pp. 245, *et seq.*

MEAN of the COLLECTIVE RESULTS of the whole SERIES of RESEARCHES (Wollny).

I. (1890).

LOWLAND PEAT SOIL.

Air Temperature.	Thermometer 6 in. deep.			Thermometer 8 in. deep.			Thermometer 10 in. deep.		
	Not treated.	Mixed with sand.	Covered with sand.	Not treated.	Mixed with sand.	Covered with sand.	Not treated.	Mixed with sand.	Covered with sand.
55°·97	59°·64	60°·76	60°·38	58°·94	60°·47	58°·85	58°·26	59°·55	57°·97
Variations in Soil Temperature									
	6·51	15·40	17·74	4·32	9·99	8·33	3·49	5·35	4·12

II. (1892).

UPLAND PEAT SOIL.

Air Temperature.	Not treated.	Covered with sand. (Temperature at 6 in. deep.)				Not treated.	Mixed with sand. (Temperature at 6 in. deep.)			
		1 in. deep.	2 in. deep.	3 in. deep.	4 in. deep.		1 in. deep.	2 in. deep.	3 in. deep.	4 in. deep.
57°·79	58°·64	59°·12	59°·23	59°·43	59°·70	58°·64	59°·57	59°·97	60°·71	60°·96
Variations in Soil Temperature.										
	5·02	8·13	10·26	12·63	15·28	5·02	8·21	11·43	15·67	17·42
III. (1893).										
57·81	59 03	60·18	60·60	60·96	61·16	59·03	60·31	60·78	61·57	61·91
Variations in Soil Temperature.										
	5·07	6·98	9·16	12·81	15·73	5·07	7·81	10·56	14·41	18·14
LOWLAND PEAT SOIL. II. (1892). Covered with Sand.						III. (1893.)				
	59·55	59·90	59·99	59·99	60·13	59·99	61·50	61·57	61·75	61·68
Variations in Soil Temperature.										
	7·02	9·97	11·62	13·96	19·19	5·45	9·32	11·12	14·47	18·77

It will be noticed, in studying the above Tables, (1) that the average daily temperature of moory soil is higher than that of the air; (2) that a very perceptible rise of temperature accompanies the treatment of the soil with sand; (3) that the rise of temperature increases with the increase in amount of the sand applied; (4) that mixing the sand with the peat is attended with better results than topdressing with the same quantity of sand; and, lastly, (5) that variations in temperature are strongly noticeable in the treated soils, the more so proportionately to the quantity of sand applied; and greater in the case of mixing than merely covering.

Professor King observed, in experiments carried out on eight Wisconsin farms, taking the thermometer readings between 1 p.m. and 4 p.m., that a considerable rise of temperature accompanied the consolidation of soils by rolling, and compares the soil temperatures of rolled and unrolled portions of the same areas with those of the air above them.*

—	Air Temperature.	Soil Temperature.			
		At 1·5 in. deep.		At 3 in. deep.	
		Rolled.	Unrolled.	Rolled.	Unrolled.
	°	°	°	°	°
Sandy, ...	56·75 F.	65·55 F.	63·50 F.	61·92 F.	59·45 F.
Clay Loam, ..	51·47	56·55	53·60	56·48	53·55
" ...	59·00	70·31	64·10	64·85	59·90
Sandy, ...	69·62	73·40	72·05	70·79	69·26
Clay, ...	72·64	79·77	78·20	73·02	71·82
Sandy Clay, ...	73·30	76·83	71·90	72·58	69·09
Yellow Clay, ...	60·80	61·34	58·82	57·38	55·58
Clay Loam, ...	79·70	89·89	86·12	81·49	76·47
Mean, ...	65·37	71·69	68·57	67·31	64·39
Difference, ...	—	3·12	—	2·92	—

From all these observations it will be seen that the temperature of soils during the day, in variable as well as in fine weather, is usually higher, often very much higher, than that of the superincumbent air. At night this is not so, for the radiation of heat from the earth, especially when the atmosphere is clear and the sky cloudless, causes a much more rapid cooling of the soil than of the air; the cooling of the soil, and of the layer of air in contact with it, frequently occasions the formation of fog close to the ground, through the condensation of moisture which the air contains; sometimes the cooling is so great as to cause the deposition of hoar frost.

---

* "The Soil," p. 232.

AERIAL CURRENTS.

Variability of Wind-direction.

The familiar fact that air when locally heated ascends, is the fundamental principle which underlies the generation of atmospheric currents. Air ascends because heat expands it, and it becomes lighter. The void which would in consequence be formed, is filled with cooler and heavier air, which rushes in from the space around, as is illustrated in the chimney draught. It is thus that the currents known as the Trade-winds originate. These winds are not experienced so far north as our latitude;* but upper currents, returning from the Torrid Zone towards the Pole, descend towards the earth, and, according to Mr. Buchan, form our prevailing W.S.W. and S.W. winds, known as the *Anti-trades*. How far this factor contributes in producing variability of wind-direction, in the British area, may be questioned; but its operation is a cause that can hardly be overlooked.

Minor influences also co-operate in producing variability, namely, those which occasion "land and sea breezes," through the alternate cooling and heating of the land during night and day respectively. These diurnal phenomena are very noticeable in hot regions, and would doubtless be felt in this country more than they are, were it not for our position on the outskirts of a large continent. The presence of the waters of the Gulf Stream, also with their fairly uniform temperature, tends to induce aërial movements towards the ocean in winter, and from the ocean towards central Europe in summer. It has been stated that the mean winter temperature of Ireland, through the proximity of the Gulf Stream, is some twenty degrees F. *higher* than that of West Russia; the summer mean temperature of Ireland is some five to ten degrees F. *lower*; and such circumstances must operate powerfully in producing atmospheric movements.

Cyclonic Winds.

The circumstances which most strongly conduce to the variability of wind direction are undoubtedly the recurring cyclonic storms, which originate near the American coast, and sweep across the

---

* They prevail between 9° and 30° N. Latitude according to Alex. Buchan, M.A. See "Handy Book of Meteorology," p. 133.

Atlantic with more or less frequency. Cyclones are popularly attributed to the more than usual heating of great volumes of air over areas of the Atlantic and the Gulf of Mexico, and over tracts of the American continent. The air becoming lighter ascends, and causes an influx of cooler air from around. The currents meeting unevenly form an eddy of immense compass, and thus the cyclone.

These peculiar currents not only maintain a rotatory motion, often as great as 100 miles per hour, in a direction which, if we could speak of them as being viewed downward, north of the equator, is uniformly against that of the hands of a clock or watch; but also pursue a curvi-linear course, at about twenty-five miles an hour, covering a distance of 5,000 miles from Barbadoes towards Newfoundland, in eight to ten days.* It is believed by some (amongst them Professor Draper, of New York) that a very large proportion of these storms cross the Atlantic from shore to shore. Other meteorologists, like Professor Loomis, maintain that after leaving the American region they undergo modifications which interfere with the possibility of predicting the time of their reaching Europe, or the place they will strike, with any degree of accuracy. Mr. R. H. Scott, F.R.S., holds the latter view, and discusses in his work, "Weather Charts and Storm Warnings," means of achieving reliable forecasts.

It is generally accepted by meteorological authorities that these storms, if they do not quite cross the Atlantic, travel great distances over the ocean, and usually reach the European region a little to the north of the British Isles, Ireland experiencing brushes of the skirts of the vast aërial eddies in their easterly progress. Occasionally they *cross* the British area, and cause a greater amount of meteorological disturbance than usual, accompanied by rainfall, which is sometimes excessive. The heavy rainfall of January, February, and March, of 1897, shown in the following Table, as given by Mr. Sowerby, Secretary of the Royal Botanical Society of London, may be accounted for by the frequent deviation of those storms from their usual course.

---

* "Physical Geography," by Ansted. The popular theory of cyclones seems wanting in this particular, namely, that it affords no satisfactory reason for the fact that they uniformly rotate in the direction above described. M. Marié Davy offers an explanation of the phenomena, which seems to be in some respects reasonable, if not entirely satisfactory. (*Météorologie Générale*, pp. 223 to 234). He says, north-east winds approaching the equator meet with more rapidly moving air, carried from the westward by the earth, over the torrid zone, thus originating the eddies. These once formed, centrifugal force tends to produce a vacuum within, towards which air rushes from above and below: the latter is warm and moist, the former cold, and probably highly charged with electricity. Being cold, this air produces condensation of the vapour in the warmer air, and the latent heat, thus set free, adds an increment to the mechanical force already in operation, and maintains the rapidity of the movement, if it does not greatly increase it. Davy even suggests that electric force, which generally accompanies these storms, contributes something towards the circulatory force of the cyclones. Clement Ley's account of cyclones supposes an *outward* flow of air above.

RAINFALL during the FIRST QUARTER of each of TEN YEARS.*

Year.	No. of Wet Days.	Total Rainfall.
		Inches.
1887, ...	37	4·90
1888, ...	59	5·99
1889, ...	37	5·06
1890, ...	47	4·84
1891, ...	30	4·13
1892, ...	38	3·50
1893, ...	47	4·93
1894, ...	48	6·31
1895, ...	34	4·12
1896, ...	37	4·55
1897, ...	51	8·62

Indications of a Cyclone.

The passing of a cyclone, with the various atmospheric indications, are in effect thus described by the Rev. Clement Ley, in "Modern Meteorology," pp. 116, 117:—

"The most usual direction of depressions is from the S.W. to the N.E. if the line of advance be over the observer, threads and filaments of thin clouds, *Cirrus*, at an altitude of 25,000 to 40,000 feet high, appear over the south-western horizon and parallel to it. Outlying streaks of these clouds, often from 20 to 100 miles in advance of the main pack, can be examined without difficulty. They terminate in the most attenuated points, often curled more or less outward and upward, kept apart by electric repulsion.

"When some of these threads have arrived at the zenith, we shall find them to travel from some point between W.S.W. and W.N.W. A little later, when an easterly wind springs up from beneath, and as the actual bank comes over us, the threads are more or less reticulated, forming a filmy sheet or canopy; the structure of which becomes less and less discernible and produces *halos* around sun or moon. Occasionally, even from the first appearance, no *structure* can be discerned; it forms a milky-looking sheet of cloud matter. This is in consequence of the atmosphere being humid, the crystals of ice (which congregate in the delicate forms known as *Cirrus*) not being sufficiently formed to arrange themselves in definite threads.

---

* There seems to be some ground for believing that alternating periods of rain and drought follow each other with cyclical regularity; concerning this, the following statement has recently been met with, in the public press:—"Professor J. Hann, of the Vienna Observatory, who has carefully analysed the rain statistics of Padua since 1725, of Milan since 1764, and of Klagenfurt since 1813, has come to the conclusion that an exact period of 35 years occurs during which the records of these three stations show that there is an alternation of wet and dry years. The following, according to Professor Hann's figures, were dry years:—1753, 1788, 1823, 1859, 1893: whilst the wet periods culminated in the years 1738, 1773, 1808, 1843, 1878. Thus the maximum of the next rainy period may be expected in 1913, and the maximum of the dry should fall in 1928. This argument is in full accord with the 'climate-period of 35 years,' recently put forward by Professor Brückner."

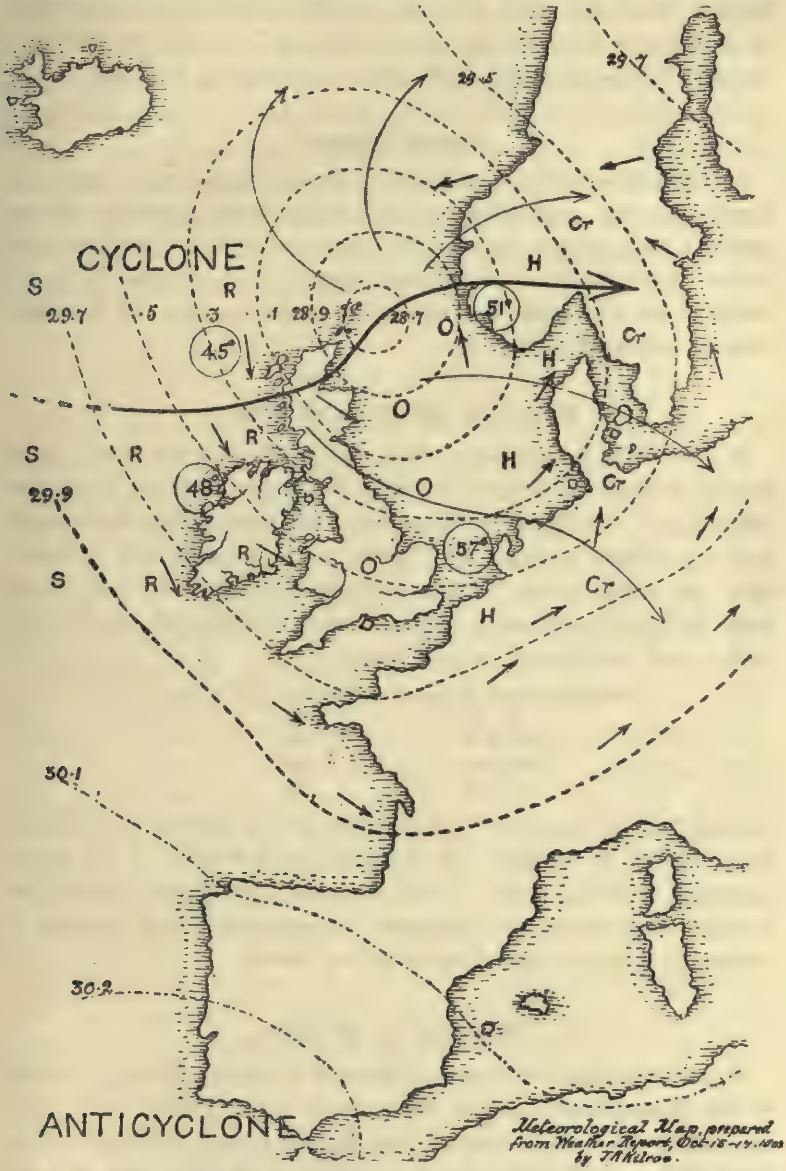
"As the bank passes over the observer it becomes lower and lower, and "the rain-bringing wind" slowly makes itself felt at the earth's surface. The upper clouds cease to be visible at all, for the sky becomes totally covered by a corporate mass of condensed vapour."

The interior parts of these gyrating storms are marked by greatly reduced barometric readings; at the centres the pressure of the atmosphere is peculiarly low; and it increases outward toward the margins of the eddies, where it is approximately normal. As a storm passes over a locality, therefore, the barometer rapidly falls till the place is reached by the centre of the cyclone, after which the barometer rises. And, as regards the directions of the wind experienced as the storm moves onward, if the centre pass to the north of Ireland in the way most usual, the direction will be perhaps first E. or S.E., then in turn S., S.W., and N.W.—the change or veering, as it is called, being "with the sun." If it take a more southerly course, and cross Ireland, the winds will change "against the sun," *backing*, as it is called, with a falling barometer—a condition which will be followed by a repetition of the storm and a rising barometer.

Galton and Ballot's Law.

A law was discovered by Galton, not fifty years ago, now recognised by all meteorologists, which is to the effect that winds blow approximately along *isobars*, or lines of equal barometric pressure, leaving regions of less pressure on the left hand than on the right, in the northern hemisphere, and the reverse in the southern. Professor Ballot enunciated substantially the same law previously, but applied it only in the limited area of Holland. This law has proved of immense service in meteorology, and was at once put to practical use on the initiative of Galton, who, in 1863, proposed the making of weather charts.

By carefully noting simultaneous barometric observations at many places, and connecting the places indicated of equal atmospheric pressure over large areas, the connecting lines are found to form concentric circles; and by comparing the positions of these circles from day to day, or more frequently, the progress of the storms may be made apparent by means of maps. There are also circles, obtainable in a similar way, surrounding



Meteorological Map, prepared from Weather Report, Oct 15–17. 1902 by J.A. Kilroe.

Fig. 63. Map representing, by means of a thick arrow, the course of a depression-centre, Oct. 15 to 17, 1902, while an anticyclone hung steadily over the extreme south-west of Europe. Short arrows, direction of surface winds; long slender arrows, directions of upper currents (after Clement-Ley); dotted lines, *isobars* giving *loci* of equal barometric pressures indicated by figures; encircled figures 51°, 57°, 45°, 48°, the temperatures, when the depression centre was east of Shetland Islands (16th Oct., 8 a.m.), 48°, 53°, 51°, 55° being the recorded temperatures in the same regions the previous day, respectively. Cr, region of *Cirrus* cloud; H, region of halos; O, overcast; R, region of rain; S, that of showers—conditions which moved with the cyclone in its eastward progress.

points on these weather charts where the barometer stands very high. These points are the centres of "Anticyclonic" systems, around which the winds circulate, at rates not at all so rapid, and in an opposite direction to that uniformly observed in cyclones: the anticyclone circulates *according to* the hands of a watch.

Cyclone Diagram.

The area involved is, as indeed the term cyclone implies, approximately circular; and if the accompanying figure, showing also an adjacent anti-cyclone, be taken to represent such an area, the successive meteorological conditions, usually experienced in each locality over which the depression (or storm) passes, will be somewhat as indicated in Fig. 63.

Directions and Rates of Wind.

It may here be explained that the wind does not blow quite parallel to the lines of equal pressure, in the case of either cyclone or anticyclone; the direction forms an acute angle with the isobars, inclining *inward* towards the centre of the former, and *outward* from the centre of the latter. A general relation has been established by Glaisher between the barometric reading and the velocity of the wind, which may be thus stated:—

Barometer	above 30	inches	indicates	130	miles a day.
"	at 30	"	"	160	"
"	29·5 to 30	"	"	210	"
"	29 to 29·5	"	"	260	"
"	below 29	"	"	320	"

Captain Maury regards 29·9 inches the normal reading of the barometer for 56 N. latitude, 29·3 inches being normal in the corresponding latitude, south. When the readings descend below the average they should be regarded as warnings; when descent is sudden it is a sure sign of approaching storms.

Frequency of Cyclones.

In summarising data for a cyclone map, from the Weekly Records of the Meteorological Office, the present writer found that thirty-one depression-centres crossed the British region during the two years 1900 and 1901, distributed according to the following table:—

	Jan. Feb. Mar.	Apr. May. June.	July. Aug. Sept.	Oct. Nov. Dec.
1900 .	6	2	3	3
1901 .	5	3	4	5

During the exceptionally wet year, 1903, some 74 depressions crossed this region—21 in the first quarter, 17 in the second, 17 in the third and 15 in the fourth.

From these data it will be perceived that depressions have been much more prevalent in the winter half year than in summer. Disturbance was caused during 1900 and 1901 by some twenty other cyclones, which crossed by the north-west, east, and south, of the British area. It was also found that the compass of the storms varied in diameter up to 2,400 miles,* and that while most came from the west, some twenty-five appear to have developed in the western European area, between parallels of 47° and 65°, and meridians 12° W. and 5° E. of Greenwich, some thirteen broke up within the same area, and several pursued courses quite divergent from the most usual S.W. to N.E. courses.

Courses of Cyclones.

Perhaps the most unusual course which could be observed is one traced by Mr. R. H. Scott, who writes as follows:—

"It has sometimes happened that a storm has advanced from the Atlantic to the coast of Kerry, but has returned and, passing out to sea again, has moved northwards along the coast until it found the opening of Donegal Bay, and has then crossed Ireland, along the tract of low land stretching from Ballyshannon to Dundalk, to the Irish Sea, where the centre often appears to be arrested for a while; or else the disturbance, clearing Ireland altogether, and crossing Scotland south of the Grampians, has passed out to the North Sea.' . . . . . 'It is found that the cyclones frequently have a tendency to move round the anti-cyclones.' . . . . . It is 'from this mutual action of the areas of high and low pressure on each other, that we gain some notion of the coasts which are likely to be visited by a storm, of the direction which the storm will take, and of the quarter where the wind in that storm will blow hardest."†

From these circumstances it will be seen that winds in the Irish region may greatly vary, both in direction and force. Dr. Lloyd. in his report on the Meteorology of Ireland,‡ has given an account of the wind directions in percentages to indicate their relative frequency in this country, as set forth in the accompanying Table, (No. 1). No. 2 of the same Table is one given by Mr R. H. Scott,§ the results of observations, by Dr. Hann, throughout Western Europe.

---

* The Hon. Ralph Abercromby writes: "A cyclone may be anything from 2,000 to 50 miles across." *Weather*, page 149.

† "Weather Charts and Storm Warnings," pp. 88, 89, 90.

‡ Transactions of the Royal Irish Academy.

§ "Elementary Meteorology," pp. 278, 280.

MEAN FREQUENCY of WINDS, in PERCENTAGES.

Region.		Season.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
For Ireland.	(1)	Summer, ...	12·3	9·4	8·9	10·0	10·7	17·1	16·3	15·7
		Winter, ...	9·6	5·2	5·0	8·6	16·4	23·4	17·6	14·4
Western Europe.	(2)	Summer, ...	9	8	7	7	10	22	21	17
		Winter, ...	6	8	9	11	13	25	17	11

It will be seen from these Tables that the most prevalent winds, both in Ireland and Western Europe, are those blowing from the S.W., W., N.W., and S., and that E. and N.E. winds are comparatively infrequent.

ATMOSPHERIC MOISTURE.

Air takes up moisture at all temperatures, and becomes charged with it when moving over sheets of water, marshes, peat bogs, and badly-drained soils. It is seldom charged to the full extent that it will bear, *i.e.*, it is seldom *saturated*. The less moisture the air contains, the greater is its drying power, or hygroscopic capacity, and the less its "relative humidity." The greater the relative humidity, the better are the atmospheric conditions, at times when, as in May and June in Ireland, herbage is likely to suffer from drought through lack of atmospheric disturbances, usually attended with rain.

Air without moisture is rarely to be met with, in our regions at least. One of the most interesting inquiries of the meteorologist is to ascertain the quantity of vapour in the atmosphere at any time and place. For this purpose various instruments have been designed, by means of which may be ascertained:—

1. The "vapour tension," *i.e.*, the barometric pressure due to the atmospheric moisture; or,
2. The actual weight of vapour contained in a cubic foot of air; or,
3. The relative humidity.

VAPOUR CONDENSATION.

The term relative humidity may be explained as the percentage of vapour contained in the air, compared with that which is necessary for its saturation at any given temperature. The following Table, taken from that compiled by Sir J. W. Moore, M.D., may here be given as illustrative of the conditions. It will be observed that the relative humidity for the summer months is lower than that for the winter months, which does not mean that in summer the air contains a less actual amount of vapour, for it usually contains a greater; but that the winter temperature being lower, the total amount for saturation is not very much greater than that which the air actually contains.

Table setting forth the Results of Observations from 1865 to 1887, upon the Temperature, Humidity, Cloudiness, Rainfall, &c., at Dublin:—

Month.	Temperature.			Relative Humidity.	Per Cent. of Clouds.
	Mean.	Max.	Min.		
January	41·3	45·3	37·3	85·4	64
February	43·0	47·2	38·8	84·9	66
March	43·3	48·2	38·3	81·9	60
April	47·8	53·6	42·0	79·6	56
May	51·9	58·2	45·5	75·9	55
June	57·8	64·3	51·3	76·8	60
July	60·8	67·2	54·4	78·0	62
August	59·8	65·9	53·7	81·9	58
September	55·8	61·4	50·2	84·3	56
October	49·8	54·6	44·9	85·5	59
November	44·5	48·7	40·3	85·9	62
December	41·1	45·1	37·1	85·7	61
Annual Means . . .	49·8	55·0	44·6	82·2	60

At night when the air cools down—through contact with the earth, itself cooled by radiation—a temperature is reached at which it can no longer retain its vapour in invisible form, for warm air has a greater capacity for vapour than cold air; the vapour then *condenses*, and becomes visible as fog, which rests on vegetation and soil as dew, or in extreme cases of cooling, as hoar frost. The temperature at which fog begins to form is called the *dew-point*. At the dew-point the condensation of vapour causes a release of latent heat, which tends to preserve the layer of air in contact with vegetation from extreme cooling—an important consideration in early spring. We may therefore say that the higher the dew-point, the less likelihood is there of injury from frost.

Meteorological Records.

In most of the published meteorological tables are set forth the Relative Humidity, or Vapour Tension, from which the degree of humidity may be ascertained by means of standard references tables. The vapour tensions are found by comparing the readings of ordinary (or, by way of contrast to the other, the *dry-bulb*) thermometers, with those of the *wet-bulb* thermometers, these instruments affording ready means of observing the conditions of the atmosphere as regards its humidity at any moment.*

Specimen tables of records, as given in the Daily Weather reports, for six Irish stations, and of hourly observations made by means of mechanism at the only Irish station of the First Order, are given at the close of this chapter. Also tables of averages of Temperature, Rainfall, and Bright Sunshine, as calculated at the Meteorological Office for long periods of years. A table of Relative Humidity for twelve Irish stations is added, the monthly averages in this case having been calculated by the writer for short periods.

WET AND DRY WINDS.

Air moving over large areas of water is highly charged with moisture: accordingly winds blowing off the Atlantic are in this condition; and when they meet with currents of colder air, say in the higher regions of the atmosphere, they lose the power of retaining all their vapour in the invisible form; when this is the case, the surplus moisture condenses as clouds, which are of different kinds, and at various elevations, some occurring at altitudes of nearly 10,000 yards. Sir J. W. Moore, in his work on Meteorology (p. 221), has given a classification of clouds which may here be reproduced:—

Group A.—Clouds from medium altitudes up to 9,000 metres (9,800 yards).

1. *Cirrus* (*a*) (or mares' tails).
2. *Cirro-stratus* (*b*) (or "sheet cloud").
3. *Cirro-cumulus* (or "mackerel sky").

Group B.—Clouds having altitudes from 3,000 metres to 6,000 metres (3,300 to 6,500 yards).

4. *Alto-cumulus* (*a*)
5. *Alto-stratus* (*b*).

Group C.—Clouds the bases of which have altitudes from 1,000 to 2,000 metres.

6. *Strato-cumulus* (*a*) ("shower cloud").
7. *Nimbus* (*b*) ("rain cloud").

Group D.—Clouds of ascending columns of air, with bases about 1,400 metres high, and summits from 3,000 to 5,000 metres.

8. *Cumulus* (*a*).
9. *Cumulo-nimbus* (*b*).

Group E.—Fog banks up to about 1,500 metres.

10. *Stratus.*

In the first four groups, (*a*) distinguishes "the forms of cloud usually accompanied by fine weather, and (*b*) for those characteristic of bad weather."

---

* See Note at end of chapter, p. 278, for Calculated Relations between Relative Humidity, Vapour Tension, and readings of Wet and Dry Bulb thermometers.

Fog, Cloud, Mist.

It has been stated that condensation renders visible the moisture previously existing in the air as vapour, and thus forms *fog*. The microscopic particles of water in fog and cloud coalesce in groups under certain circumstances, especially when particles of dust are present, and form appreciable globules, as seen in mists; and such globules may again group themselves together, and form drops of rain.

As a rule, if a damp wind become chilled by a colder atmosphere, condensation will probably take place, and often precipitation—rain. If, on the contrary, a chilly wind bearing little moisture. meet a warmer atmosphere over land, then no condensation will be likely to occur. This is generally, though not always the case, with easterly and north-east winds, which are therefore practically dry winds in our region.

Condensation also takes place around mountain tops, and in hilly districts, more than over plains. The appearance of clouds in such places is a familiar indication of the probable approach of rain; the cooling effect of high land, which loses temperature with increase of altitude, renders manifest the humid condition of the atmosphere, which would otherwise scarcely be suspected. The heat of the sun, and radiation from the earth, combined, tend to preserve the moisture in the invisible form; when the influence of both of these slackens towards the afternoon, humidity often asserts itself; first appearing in the higher grounds, and then descending in mist or rain—the precipitation becoming general.

The prevalence of fogs and mists, with frequent rains, is the baneful characteristic of hilly regions, experienced generally by the poorer class of tenant farmers, to whom it yields the unwelcome consequences of soils impoverished by drenching, late springs, and late and damp harvests. Sunshine, which would warm at least the slopes facing southward, is intercepted by the fogs hanging about the colder hill sides; and thus condensation spreads, till the tracts are, as is often the case, wholly merged in fog and mist. The frequency of sheets of fog over low-lying damp, and consequently chilly tracts, has already been mentioned (p. 249).

Rainfall.

In considering the local variation presented in Ireland, by the rainfall record given in the Tables for the British Isles, compiled by Mr. G. J. Symons, F.R.S., and published by the Meterological Council, one of the most interesting points noticeable is the difference which obtains between the records at high and low level stations, in the same districts. The readings at the former are generally much higher than those at the latter, a circumstance for which the reader is prepared by what has immediately preceded this paragraph. The following Table, selected and arranged from records given in Symons' Tables, will sufficiently exhibit the relation between those of high and low-lying stations:—

ANNUAL RAINFALL at ELEVATED and LOW-LYING STATIONS.

County.	Station.	Height in Feet.	Rainfall.
			Inches.
Antrim, ...	Ballynure, ...	400	44·66
" ...	Belfast, ...	68	32·83
Down, ...	Windy Gap, ...	1,625	56·05
"	Banbridge. ...	230	24·63
Armagh, ...	Armagh, ..	205	31·17
" ...	Moy, ...	61	28·76
Meath, ...	Kells, ...	230	39·91
"	Aclare House, ...	170	31·46
Dublin, ...	Glen-na-Smoil, ...	516	43·72
" ...	Terenure, ...	125	25·32
Wicklow, ...	Laragh, ...	460	52·23
" ..	Greystones, ...	68	36·10
Tipperary, ...	Derrycastle, ...	580	46·08
" ...	Caher, ...	193	29·49
Kerry, ...	Mangerton, ...	1,760	77·75
"	Derrynane, ...	13	44·46
Cork, ...	Dunmanway, ...	500	61·23
"	Mallow, ...	230	26·12
Waterford, ...	Cappoquin, ...	283	34·96
"	Waterford, ...	88	29·07

Amongst the exceptions, Killybegs may be instanced. This place shows a rainfall of 61·61 inches at thirty feet elevation, while at Malin Head 38·26 inches only, at 220 feet, have been recorded. Killybegs is on the margin of a mountainous tract, and is itself surrounded by low hills, which doubtless accounts for its high record; while the south-west winds are, to a large extent, drained of their moisture by the Donegal highlands before Malin Head is reached.

Judging from what precedes, it is not surprising to find that the wettest regions in Ireland—those showing the greatest annual rainfall—are those which margin the coast, for well-nigh its entire length; for here the highest grounds are situated. The line which runs inside the hilly tracts, and approximately separates the regions of greatest from those of least rainfall, commences, say, at Lough Foyle, striking south-westward to Lower Lough Erne, and follows the line of the lakes towards Belturbet. It then strikes west towards Tobercurry, thence due south to Limerick, runs by Tipperary, Clonmel, Thomastown (in Kilkenny), and thence by Naas to the sea at Dublin. Such a line is also traceable within the Mourne Mountains and the hills of East Antrim.

Selecting the records of a few stations, the following Tables, also prepared from Symons' "British Rainfall," will present to the reader a means of comparing the amounts observed in the regions of greatest and least precipitation throughout Ireland for 1879 and 1896. The results obtained at very elevated stations, calculated to give a distorted comparison, are omitted; and *wet days* are explained to be those which gave more than ·01 inch of rainfall.

REGIONS of GREATEST RAINFALL.

Station.	County.	1879.		1896.		Height in feet.
		Rainfall.	Wet days.	Rainfall.	Wet days.	
		Inches		Inches.		
Brook Lodge, ...	Waterford, ...	38·80	181	34·94	163	104
Enniscorthy, ...	Wexford, ...	44·83	213	38·32	181	420
Kenmare, ...	Kerry, ...	59·39	184	58·15	302	74
Miltown Malbay,	Clare, ...	40·34	230	44·02	212	400
Queen's College,	Cork, ...	38·40	161	32·22	179	56
Inishtioge, ...	Kilkenny, ...	42·20	201	37·76	165	400
Mountshannon, ..	Sligo, ...	38·01	196	42·27	240	70
Queen's College,...	Galway, ...	42·10	215	39·58	207	26
Enniskillen, ..	Fermanagh, ...	48·89	174	—	—	250
Inver, ...	Donegal, ...	42·65	—	—	—	—
	Averages, ...	43·56	195	36·36	206	199

REGIONS of LEAST RAINFALL.

Station.	County.	1879.		1896.		Height in feet.
		Rainfall.	Wet days.	Rainfall.	Wet days.	
		Inches.		Inches.		
Greenore, ...	Louth, ...	37·53	206	29·43	204	4
Glasnevin, ...	Dublin, ...	28·00	184	29·33	169	56
Birr, ...	King's County, ...	32·35	211	32·42	189	183
Observatory, ...	Armagh, ...	32·27	202	31·21	214	208
Abbeyleix, ...	Queen's County,	33·13	205	33·51	197	532
Omagh, ...	Tyrone, ...	38·15	227	37·28	217	300
Castlecoote, ...	Roscommon, ...	—	—	37·78	172	197
Castlelough, ...	Tipperary, ...	37·76	222	39·44	206	120
Brownshill, ...	Carlow, ...	35·96	209	32·70	169	291
Ballymoney, ...	Antrim, ...	—	—	37·60	254	170
	Averages, ...	34·39	208	34·07	199	206

Tables giving the average rainfall at fourteen stations in Ireland, as calculated for a period of thirty years, are given at the close of this chapter.

WEATHER PROGNOSTICATION.

Everyone concerned in the material interests of agriculturists knows that prosperous cultivation depends almost as much upon favourable weather conditions, as upon the qualities of soils or methods of soil treatment. To forecast weather changes in harvest time would be a welcome achievement, the advantages of which, if it were at all possible, would be so apparent and palpable, as to justify any means by which it could be attained. What has come before the reader in this chapter is sufficient to show what great difficulties lie in the way of attempts to give reliable forecasts. The barometer is known to furnish some help in prognostication; but the readings of this instrument are affected by such a variety of circumstances, that it is only when they are taken in conjunction with other observations, that it can be of much utility.

The causes which conjointly operate in maintaining a high or low barometer, are summarized by Professor Mohn * somewhat as follows, as given by R. H. Scott:—†

The barometer stands high—

(1). When the air is very cold, for then the lower strata are denser and more contracted than when it is warm.

(2). When the air is dry, for then it is denser than when it is moist.

(3). When in any way an upper current sets in towards a given area, for this compresses the strata underneath.

The barometer stands low—

(1). When the lower strata are heated, causing the surfaces of equal pressure to rise, and the upper layers to slide off . . . for by this means the mass of air pressing on each unit of area below is reduced.

(2). When the air is damp, for the density of vapour is much less than that of air at the same temperature, and, consequently, the mixture of air and vapour is lighter than air without vapour.

(3). When the air, from any cause, has an upward movement; for this, of course, acts in the same manner as (1).

Mr. Scott gives the characteristic indications of a cyclonic disturbance, as manifested in their simplest form, which serves to illustrate the advantage of noting barometric readings in conjunction with those of the thermometer, the forms of clouds, and

---

* *Grundzüge der Meteorologie*, 3rd ed., p. 214.

† "Elementary Meteorology," p. 249.

direction of aerial currents. Speaking of a cyclone, he says: * The phenomena belonging to the front of the system are *Cirrus* clouds (mares' tails) in the sky, south-easterly winds, great rise of the *thermometer*, and excessive dampness. The sky becomes gradually overcast, followed by mist and rain. The *barometer* falls persistently, while *scud* begins to drift from the southward. The *barometer* continues to fall, the wind *veering* from S. to S.W., rain falling. As soon as the wind passes the S.W. and draws to the W. or N.W. the *barometer* begins to rise with a sudden jump, and the temperature falls, with very heavy showers of rain, possibly turning to hail, connected with and following which the air becomes drier and the sky clears.

Applications of Meteorology.

Although weather prognostication in Ireland is attended with special difficulties because of its insular position, and the fact that disturbances in atmospheric conditions approach us from the westward, there is little doubt that by means of systematic meteorological observations, something might be done towards combating the unfavourable characteristics of our climate.

Even without this, agriculturists would find it to their advantage to note the following points set forth in published Meteorological Tables, the utility of which has already been explained, viz:—

(1). The monthly mean readings of the thermometer for the year, with the greatest, least, and average readings for a period of years.

(2). The greatest and least daily readings for each month—say from the middle of March to the middle of June. These data would be serviceable during the season of germination and early plant growth.

(3). The monthly rainfall for the year; a useful record to show the different degrees of drenching to which different localities are liable, and the consequent proportionate waste of soil ingredients, which has to be made good to maintain fertility.

(4). The number of wet, showery, and overcast and cloudy days for each month, at least from February to October inclusive, covering the periods of spring and harvest operations, and of autumn ploughings.

(5). Hygrometric readings, showing daily relative humidity of the atmosphere, for May and June at least; useful in connection with the initial stages of turnip growing, and occasional droughts through lack of disturbance in atmospheric conditions.

(6.) Table of wind directions, and pressures, and giving the number of calm days for each month.

---

* "Weather Charts and Storm Warnings" (p. 61), by R. H. Scott, F.R.S

Concluding Remarks.

Notwithstanding recognised difficulties in forming reliable forecasts in this country, there is no doubt that patient, steady, and systematic use of the barometer and thermometer, with close observation of such phenomena as the forms and movements of clouds, would reward those whose care it is to combat or forestall the unfavourable weather conditions which assail us. If these observations were supplemented by some others collected, say, at the stations along the western seaboard, used conjointly with information received from many quarters at the Meteorological Office in London, arranged suitably for transmission, at a subsidiary office in Dublin, and despatched by wire to country parts, there is little doubt that material help could, by such means, be given to farmers in the harvest season. The help would be especially valuable in barley-growing districts. This crop—an important one in the country—is particularly liable to injury by bad harvesting, and even ten or twelve hours of warning might admit of the reaped crop being secured against danger.

Elaborate as are the arrangements, and suitable the circumstances for the prognostication of weather changes in the wide area of the United States, the use of Meteorology for these purposes is not the only practical one to justify—in so far as agricultural matters are concerned—the large expenditure of public money upon the science, in that country. There are, besides, notes upon agricultural operations and crop prospects recorded weekly, concurrently with the state of the weather in each of the districts, and comparisons of the latter with average conditions, founded upon many years' observation. This is an application of the science which might, with advantage, lend itself to the same purposes in Ireland. Quarterly reports of rainfall are issued, and comparisons with the averages drawn, for north and south of Ireland, by the Meteorological Office, but these are much too general to serve any practical ends; the districts even are larger than those in England. If the best possible averages were made out for districts in Ireland, defined by their presenting fairly distinct meteorological characteristics, and reports of current observations made from week to week, in spring and summer, to compare with averages, and connect with crop conditions and agricultural operations, the results would be useful—if only in correcting the tendency to procrastination in spring preparations and sowing; a sounder basis of harvest anticipations than at present exists, would be afforded; method and exactitude would be induced; and habits of observation begotten, which could not fail in many respects to prove beneficial to the country, especially to the farming community.

Meteorological Tables.

Concluding this chapter, tables of such averages as those abovementioned, are given for Irish stations, as quite recently published by the Meteorological Office; preceded by two, to serve as samples of daily records upon which the averages are based, and followed by a table giving the relative humidity observed at several Irish stations.

SPECIMEN TABLE I. of Daily Weather Report, for Six Irish Stations, as presented for the Evening of April 14th and Morning of April 15th, 1901, a day on which an important Cyclonic Depression was passing east by south across the British Area, occasioning much Atmospheric Disturbance with rain.

STATION.	Barometer.	Temp.	Wind.		Weather.	Barometer.		Temperature.			Wind.		Weather.	Sea 0 to 9.
	At 32° F. and M.S.L. Ins.	Dry Bulb.	Direction.	Force 0 to 12.		At 32° F. and M.S.L. Ins.	Change since yesterday.	Dry Bulb.	Wet Bulb.	Change since yesterday.	Direction.	Force 0 to 12.		
Malin Head .	39 18	42°	W.N.W.	7	c.h.r.q.	29·23	— ·03	40°	38°	—4	N.W.	5	c.h.q.	4
Blacksod Point .	29·37	44	W.N.W.	6	c.q.	29·10	·00	40	40	—7	N.W.	5	b.c.h.p.	4
Parsonstown .	29·45	41	S.W.	1	o.	29·46	+ ·02	37	37	—11	W.	1	r.	-
Donaghadee .	29·28	45	W.	5	b.	29·28	— ·07	40	37	—4	W.N.W.	4	c.q.	3
Valencia . .	29·56	47	W.S.W.	6	o.p.	29·59	— ·02	44	40	—5	W.	5	o.p.	6
Roche's Point .	29·55	49	W.N.W.	5	c.q.	29·55	+ ·01	41	41	—7	W.N.W.	5	b.c.q.	4

EXPLANATION OF ABBREVIATIONS AND REFERENCE LETTERS.

Barometer readings, given in inches (Ins.), are reduced for temperature, and mean sea level (M.S.L).

Weather: Beaufort Scale is—b. blue sky; c. detached clouds; h. hail; o. overcast; p. passing showers; q. squally; r. rain.

TABLE II.—SHOWING the AVERAGE TEMPERATURES (DEGREES F.) for EACH MONTH and for the WHOLE YEAR, at CERTAIN of the STATIONS which furnish RETURNS for the WEEKLY WEATHER REPORTS and MONTHLY SUMMARIES, derived from Observations extending over the 30 Years 1871–1900.

No.	STATIONS.	January.			February.			March.		
		Max.	Min.	Mean.	Max.	Min.	Mean.	Max	Min.	Mean.
1	Malin Head	45°·1	37°·8	41°·4	45°·4	38°·3	41°·8	46°·4	38°·5	42°·4
2	Londonderry	44·5	35·1	39·8	46·4	35·7	41·1	48·9	36·2	42·5
3	Donaghadee	44·5	36·0	40·3	45·6	36·5	41·1	47·5	37·0	42·3
4	Edenfel	42·6	32·8	37·7	44·4	33·7	39·1	46·8	34·4	40·6
5	Armagh	43·3	34·1	38·7	45·1	35·0	40·1	47·6	35·1	41·4
6	Markree Castle	44·7	33·8	39·3	46·4	34·7	40·6	48·9	35·0	42·0
7	Blacksod (Belmullet)	46·5	38·8	42·7	47·3	38·8	43·0	48·4	39·1	43·8
8	Dublin (City)	45·8	37·3	41·6	47·0	37·9	42·5	49·0	38·2	43·6
9	Birr Castle	45·2	33·8	39·5	46·9	35·0	41·0	49·8	34·8	42·3
10	Kilkenny	45·9	35·4	40·7	47·0	36·6	41·8	50·0	36·5	43·3
11	Foynes	46·4	36·0	41·2	47·5	38·3	42·9	50·4	36·9	43·7
12	Killraney	48·1	38·0	43·1	48·7	38·2	43·4	51·0	38·4	44·7
13	Valencia	49·1	39·9	44·5	49·5	40·4	45·0	50·9	41·0	45·5
14	Roche's Point	47·5	39·1	43·3	48·3	39·6	44·0	49·7	39·6	44·6

No.	STATIONS.	July.			August.			September.		
		Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
1	Malin Head	61°·0	53°·6	57°·3	61°·8	54°·1	58°·0	58°·5	51°·2	54°·9
2	Londonderry	66·1	51·5	58·8	65·6	51·5	58·6	61·6	47·6	54·6
3	Donaghadee	63·5	52·1	57·8	62·8	52·5	57·7	60·1	49·3	54·7
4	Edenfel	64·3	50·3	57·3	63·9	50·0	57·0	59·6	46·3	53·0
5	Armagh	65·4	51·2	58·3	4·7	51·2	58·0	60·3	47·2	53·8
6	Markree Castle	64·7	50·2	57·5	64·7	50·0	57·3	61·1	46·2	53·7
7	Blacksod (Belmullet)	62·4	53·8	58·1	62·7	54·1	58·4	59·8	51·6	55·7
8	Dublin (City)	66·5	54·0	60·3	65·7	53·7	59·7	61·6	50·1	55·9
9	Birr Castle	66·4	51·7	59·1	65·9	51·6	58·8	61·9	47·3	54·6
10	Kilkenny	67·0	52·1	59·6	66·5	52·5	59·5	61·9	48·6	55·3
11	Foynes	64·8	51·7	58·2	65·1	52·7	58·9	61·9	48·9	55·4
12	Killarney	65·5	52·3	58·9	65·8	53·3	59·5	62·2	49·7	55·9
13	Valencia	64·0	53·8	58·9	64·7	54·3	59·5	61·9	51·4	56·7
14	Roche's Point	65·8	53·7	59·7	65·7	54·2	60·0	61·9	51·3	56·6

[*continued.*

TABLE II.—SHOWING the AVERAGE TEMPERATURES (DEGREES F.) for EACH MONTH and for the WHOLE YEAR, at CERTAIN of the STATIONS which furnish RETURNS for the WEEKLY WEATHER REPORTS and MONTHLY SUMMARIES, derived from Observations extending over the 30 Years 1871-1900—*continued.*

No.	STATIONS.	April.			May.			June.		
		Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
1	Malin Head . .	50°·0	41°·7	45°·9	54°·2	45°·5	49°·8	59°·1	50°·8	55°·0
2	Londonderry . .	54·4	39·5	47·0	59·7	43·4	51·6	65·4	49·1	57·3
3	Donaghadee . .	51·4	40·5	45·9	56·2	44·5	50·3	61·6	49·7	55·6
4	Edenfel . . .	52·4	37·5	45·0	57·9	41·5	49·7	63·5	47·5	55·5
5	Armagh . . .	52·8	38·4	45·6	58·1	42·6	50·4	64·0	48·5	56·3
6	Markree Castle .	53·9	38·2	46·1	58·0	41·9	50·0	63·3	47·4	55·4
7	Blacksod (Belmullet)	52·2	42·6	47·4	55·8	46·1	51·0	60·9	51·3	56·1
8	Dublin (City) . .	53·5	41·6	47·6	58·7	45·5	52·1	64·6	51·4	58·0
9	Birr Castle . .	54·9	38·6	46·8	59·8	42·8	51·3	65·1	48·8	57·0
10	Kilkenny . . .	54·5	40·0	47·3	59·7	43·7	51·7	64·4	50·2	57·3
11	Foynes . . .	54·7	40·0	47·4	58·0	44·7	51·4	63·9	49·8	56·9
12	Killarney . . .	54·2	41·3	47·7	59·2	44·8	52·0	63·2	50·4	56·8
13	Valencia . . .	54·2	43·1	48·7	58·2	46·3	52·3	62·5	51·3	56·9
14	Roche's Point . .	53·8	42·7	48·2	58·6	46·4	52·5	64·2	51·6	57·9

No.	October.			November.			December.			Whole Year.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
1	52°·6	45°·6	49°·1	48°·3	41°·2	44°·3	45°·4	38°·3	41°·9	52°·3	44°·7	48°·5
2	54·0	42·1	48·1	48·4	38·4	43·4	45·0	35·0	40·0	55·0	42·1	48·6
3	53·7	43·5	48·6	48·8	39·7	44·3	46·1	36·6	41·4	53·5	43·2	48·3
4	52·2	40·0	46·1	46·9	36·4	41·7	43·0	32·5	37·8	53·1	40·2	46·7
5	53·1	41·3	47·2	47·7	37·6	42·7	43·5	34·2	38·9	53·8	41·4	47·6
6	54·3	40·0	47·4	49·0	37·2	43·1	45·0	33·8	39·4	54·5	40·7	47·6
7	54·2	45·9	50·1	49·7	41·7	45·7	47·2	39·2	43·2	53·9	45·3	49·6
8	54·5	44·2	49·4	49·9	40·9	45·4	46·1	37·3	41·7	55·2	44·3	49·8
9	54·7	40·5	47·6	49·4	37·2	43·3	45·5	34·0	39·8	55·5	41·3	48·4
10	54·8	42·1	48·5	50·0	38·6	44·3	45·8	35·6	40·7	55·6	42·6	49·1
11	55·3	42·6	49·0	50·6	39·4	45·0	46·7	37·3	42·0	55·4	43·2	49·3
12	56·1	44·0	50·4	51·6	39·8	45·7	48·2	38·3	43·3	56·2	44·0	50·1
13	56·4	46·3	51·4	52·4	43·0	47·7	50·1	40·6	45·4	56·2	45·9	51·1
14	55·9	46·0	51·0	51·4	42·3	46·9	48·5	39·9	44·2	55·9	45·5	50·7

TABLE III.—Showing the AVERAGE RAINFALL (*inches*) and the AVERAGE NUMBER of RAIN-DAYS for EACH MONTH and for the WHOLE YEAR, at CERTAIN STATIONS which furnish RETURNS of the WEEKLY REPORTS and MONTHLY SUMMARIES, derived from OBSERVATIONS extending over 35 Years 1866 to 1900.

No.	STATIONS.	January.		February.		March.	
		Total.	Days.	Total.	Days.	Total.	Days.
1	Malin Head (1886-1900)	2·44	22	2·06	17	2·06	19
2	Londonderry . . .	3·83	23	2·37	20	2·82	20
3	Donaghadee . . .	2·80	20	2·33	17	1·96	18
4	Edenfel	3·43	21	2·53	18	2·45	20
5	Armagh	2·70	19	2·21	16	2·05	17
6	Markree Castle (1871-1900).	3·74	22	2·87	20	2·85	20
7	Blacksod (Belmullet) (1876-1900).	4·75	26	3·54	20	3·47	23
8	Dublin (City) . . .	2·23	18	1·99	16	1·95	16
9	Birr Castle . .	2·91	20	2·12	16	2·23	16
10	Kilkenny	3·37	19	2·50	17	2·07	15
11	Foynes (1881-1900) . .	3·54	19	3·05	17	2·52	15
12	Killarney (1881-1900) .	6·29	21	5·30	19	4·11	17
13	Valencia	6·10	24	4·94	21	3·92	20
14	Roche's Point . . .	5·14	20	4·09	17	3·26	14

No.	STATIONS.	July.		August.		September.	
		Total.	Days.	Total.	Days.	Total.	Days.
1	Malin Head (1866-1900)	2·87	19	3·25	21	3·11	19
2	Londonderry . . .	3·40	21	3·87	22	3·64	19
3	Donaghadee . . .	2·83	18	3·30	19	2·80	17
4	Edenfel	3·34	20	3·89	20	3·47	19
5	Armagh . . .	3·14	19	3·26	19	2·84	18
6	Markree Castle (1871-1900).	3·58	22	4·15	24	3·83	21
7	Blacksod (Belmullet) (1876-1900).	2·94	21	4·98	22	3·99	21
8	Dublin (City). . .	2·56	18	3·04	17	2·22	15
9	Birr Castle . . .	2·95	17	3·87	18	2·92	17
10	Kilkenny . . .	2·58	15	3·50	15	2·72	14
11	Foynes (1881-1900) . .	3·11	19	4·20	19	3·01	17
12	Killarney (1881-1900) .	3·52	16	4·78	19	3·85	18
13	Valencia	3·95	20	4·96	22	4·31	19
14	Roche's Point . . .	3·00	15	3·94	16	3·62	14

[*continued.*

TABLE III.—Showing the AVERAGE RAINFALL (*inches*) and the AVERAGE NUMBER of RAIN-DAYS for EACH MONTH and for the WHOLE YEAR, at CERTAIN STATIONS which furnish RETURNS of the WEEKLY REPORTS and MONTHLY SUMMARIES, derived from OBSERVATIONS extending over 35 Years 1866 to 1900—*con.*

No.	STATIONS.	April.		May.		June.	
		Total.	Days.	Total.	Days.	Total.	Days
1	Malin Head (1886-1900)	1·80	17	2·14	16	2·21	15
2	Londonderry . . .	2·34	17	2·46	18	2·70	17
3	Donaghadee . . .	1·94	15	2·19	15	2·18	15
4	Edenfel	2·27	17	2·39	17	2·81	17
5	Armagh	2·10	16	2·12	16	2·34	16
6	Markree Castle (1871-1900).	2·34	18	2·52	19	3·15	17
7	Blacksod (Belmullet) (1876-1900).	2·81	19	2·81	18	2·69	17
8	Dublin (City) . . .	1·95	15	2·02	15	1·92	15
9	Birr Castle . . .	2·14	15	2·37	15	2·43	15
10	Kilkenny	2·21	16	2·11	15	2·35	14
11	Foynes (1881-1900) . .	2·47	16	2·32	14	2·51	15
12	Killarney (1881-1900) .	3·37	16	3·01	15	2·85	15
13	Valencia	3·78	18	3·02	16	3·38	17
14	Roche's Point . . .	3·10	15	2·93	13	3·02	13

No.	October.		November.		December.		Annual.	
	Total.	Days.	Total.	Days.	Total.	Days	Total.	Days.
1	2·99	21	3·08	20	3·36	24	31·37	230
2	4·22	23	4·05	20	4·12	23	40·32	243
3	3·14	18	3·12	19	2·96	21	31·55	212
4	3·79	20	3·61	21	3·82	21	37·80	231
5	2·98	18	2·83	19	2·92	19	31·49	212
6	4·30	21	4·00	21	4·31	23	41·64	248
7	5·20	23	5·22	24	6·12	27	48·52	261
8	2·94	18	2·56	17	2·39	18	27·77	198
9	3·06	18	2·97	19	3·17	20	33·04	206
10	3·13	18	2·94	19	3·36	18	32·84	195
11	3·81	19	4·19	19	4·65	20	39·38	208
12	5·66	21	6·29	22	7·41	22	56·47	223
13	5·61	22	5·67	22	6·34	25	56·01	246
14	4·21	16	4·65	19	5·47	20	46·43	192

TABLE IV.—Showing the Average Number of Hours of Bright Snnshine for each Month and for the Whole Year, together with the Percentages of the Possible Duration, in each instance, at certain of the Stations which furnish returns for the Weekly Weather Reports and Monthly Summaries, derived from Records extending over the 20 Years 1881–1900.*

STATIONS.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Annuals.	
	Hours.	Per Cent.	Hours.	Per Cent.	Hours.	Per Cent.	Hours.	Per Cent.	Hours.	Per Cent.	Hours.	Per Cent.	Hours.	Per Cent.	Hours.	Per Cent.	Hours.	Per Cent.	Hours.	Per Cent.	Hours.	Per Cent.	Hours.	Per Cent.	Hours.	Per Cent.
Armagh . .	45·9	19	64·0	24	103·1	28	140·7	34	184·6	38	172·2	34	141·4	28	125·9	28	116·5	31	91·0	28	58·1	23	37·3	17	1280·7	29
Markree . .	43·5	18	64·2	24	105·2	29	145·8	35	188·6	38	168·1	33	129·5	26	129·7	29	107·7	29	89·9	28	55·2	22	33·5	15	1260·7	29
Dublin (Phœnix Park).	59·1	24	72·1	27	123·9	34	162·4	39	212·5	44	197·3	40	166·8	33	162·7	36	143·4	38	110·6	34	70·9	28	52·6	23	1534·3	35
Birr Castle . .	52·0	21	68·0	25	110·8	30	151·1	36	185·0	38	170·2	34	139·2	28	139·5	31	129·2	35	99·9	31	63·8	25	44·7	20	1353·4	31
Valencia . .	54·5	22	73·5	27	132·3	36	163·9	40	210·7	44	197·6	40	154·4	31	152·7	34	133·1	36	104·4	32	65·8	26	42·6	18	1485·5	34
Blackpool . .	36·5	15	62·5	23	106·7	29	148·5	36	198·6	40	192·3	38	182·7	36	155·0	34	121·8	33	89·9	28	43·0	17	24·7	11	1362·2	31
Pembroke . .	54·1	22	77·6	28	135·2	37	179·6	44	223·9	46	233·6	47	205·3	42	193·8	43	148·3	40	104·9	32	60·9	24	44·0	19	1661·2	38
Plymouth . .	50·6	19	77·6	28	136·0	37	172·1	42	217·8	46	217·1	45	208·0	43	197·3	45	154·6	41	108·4	33	61·7	23	51·0	21	1652·2	37
York . . .	35·2	12	58·9	22	106·5	29	134·2	32	183·3	37	171·6	34	174·8	35	148·2	33	118·2	32	85·9	27	37·6	15	24·9	11	1274·3	29
Rothamsted .	45·5	18	68·6	25	119·9	33	148·1	36	196·2	41	191·2	39	211·5	43	189·5	42	144·7	39	110·2	34	59·1	23	42·9	18	1527·4	35

* Records at some English Stations added for comparison.

TABLE V.—Showing Monthly Averages of Relative Humidity, at Valencia and Eleven Stations of the Second Order, for periods of Five Years 1894 to 1898 inclusive; except Mount Nugent and Killarney, Records from which ceased in 1896, and Brookborough, Records from which ceased in 1895.

STATION.	Height above Sea.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov	Dec.
	Feet.												
Londonderry, ...	67	87·3	86·6	85·4	82·2	78·3	80·9	81·9	85·1	86·8	88·5	89·0	88·6
Lissan, ...	300	90·8	89·4	89·2	84·8	78·8	82·2	83·8	85·8	87·6	90·4	90·8	90·2
Armagh, ...	196	91·5	89·3	86·6	84·1	79·1	82·2	82·4	84·9	87·2	89·2	90·0	91·8
Mount Nugent, ...	262	92·1	91·6	89·8	86·0	78·9	81·2	85·8	87·8	89·1	90·0	92·3	93·7
Brookborough, ...	271	88·6	86·0	87·6	85·3	78·9	81·9	85·4	88·4	87·0	91·1	91·7	92·2
Markree, ...	122	91·6	89·2	86·9	84·3	79·5	82·7	84·3	86·3	87·3	88·1	89·5	89·7
Glasnevin, ...	67	91·2	90·5	89·6	89·4	88·4	87·8	84·0	88·6	88·5	90·6	90·5	90·9
Phœnix Park, ...	155	86·5	84·7	83·7	81·4	78·6	80·4	80·0	82·6	85·3	86·5	86·2	86·1
Dublin City, ...	47	85·7	83·7	83·1	80·8	78·3	78·6	79·4	82·5	86·2	88·0	86·9	86·3
Parsonstown, ...	175	90·3	88·4	86·2	82·3	77·7	79·0	82·1	85·1	85·9	87·8	89·7	90·1
Killarney, ...	86	89·0	86·3	86·3	84·7	81·0	82·3	86·0	87·6	88·5	87·5	88·0	89·5
Valencia, ...	30	87·3	87·2	85·8	84·2	79·8	82·5	84·8	86·8	85·7	85·7	87·7	88·6

A specimen Record at Valencia for twenty-four hours, on same date of Table I., is also here presented. The observations at this—the only Station of the First Order in Ireland—are taken by means of mechanism. The figures have been kindly supplied to the writer by the Secretary of the Meteorological Council, W. N. Shaw, Esq., SC.D., F.R.S.

TABLE VI., showing the HOURLY Values of VALENCIA OBSERVATORY of the BAROMETER, TEMPERATURE, VAPOUR TENSION, WIND, and RAINFALL for the 15th April, 1901.

Hour.	Barometer.	Temperature.		Vap. Ten.	Wind.		Rainfall.
		Dry.	Wet.		Dirn.	Vely.	
	In.			In.	Pts.	Miles.	In.
1 a.m. . .	29·552	44°·9	41°·2	·227	W. & N.	35	-
2 " . . .	·545	44·9	40·0	·198	W.	32	-
3 " .	·540	44·9	41·6	·226	W. & S.	32	·005
4 " . .	·542	42·1	40·8	·240	W. & N.	30	·010
5 " . .	·529	43·7	41·4	·235	W. & S.	36	·005
6 " . .	·524	43·9	40·5	·208	W. & N.	36	-
7 " . .	·531	42·3	40·6	·233	W. & N.	33	·020
8 " .	·534	42·2	40·5	·233	W. & N.	33	·005
9 " . .	·550	43·5	39·9	·208	W. & N.	35	·040
10 " . .	·560	44·9	41·9	·232	W.N.W.	35	-
11 " . .	·570	46·2	42·6	·234	W. & N.	33	-
Noon . .	·592	46·8	42·0	·217	W. & N.	33	-
1 p.m. . .	·598	42·8	41·9	·255	W.N.W.	41	·035
2 " . .	·605	46·9	41·9	·215	W. & N.	42	-
3 " . .	·614	47·7	42·5	·217	W.	43	-
4 " . .	·625	47·2	43·9	·249	N.W.& W.	31	-
5 " . .	·630	48·2	43·9	·239	W. & N.	40	-
6 " . .	·635	47·8	43·9	·243	W. & N.	40	-
7 " . .	·646	45·9	42·5	·236	W.	34	-
8 " . .	·655	46·6	42·3	·225	W. & N.	42	-
9 " . .	·674	45·3	42·5	·250	W. & N.	43	·005
10 " . .	·681	46·3	42·8	·236	W. & N.	42	-
11 " . .	·684	46·7	43·4	·244	W. & N.	42	-
Midnight . .	29·699	46·6	43·2	·242	W. & N.	42	-

NOTE ON EVAPORATION FROM TREES.

Some interesting experiments in 1849–1850, upon the evaporation from evergreens and deciduous trees, by Sir John B. Lawes, gave the following results, taken from the Rothamsted Report (pp. 1-9), re-printed in 1894 by Spottiswoode and Co., London :—

Amongst the plants exeprimented upon were :—

Spruce fir,	weighing	15	oz.	160	grains.
Larch,	„	4	„	170	„
Oak,	„	2	„	370	„
Ash,	„	4	„	40	„
Sycamore,	„	2	„	24	„

Table showing the aggregate Loss, in grains, of Water Evaporated, obtained by Frequent Weighings, during the Most and Least Active Periods of Growth. Also Loss (*i.e.* the amount evaporated) as compared with weight of Each Plant :—

Plant.	Evaporated, May 14 to Oct. 21 (grains.)	Evaporated, Oct. 21 to May 14 (grains.)	Loss 1st Period Plant=1.	Loss 2nd Period Plant=1.
Spruce Fir, ..	73,660	60,690	10	7 (nearly)
Larch, ...	97,280	17,020	46	8
Oak, ...	66,510	14,080	50	10·6
Ash, ...	104,940	10,350	53·5	5·3
Sycamore, ...	120,910	12,500	123 (nearly)	12·7

Another Table prepared from data given in the same pamphlet shows the average daily Evaporation.

Table showing the Daily Evaporation from Oak, Ash, and Sycamore Plants, during the Active Period of Growth :—

Dates—Ten. and Thirty-day Periods.	Loss per diem—(Grains).			Mean temperature of day Fahr.	Hydrometer.
	Oak.	Ash.	Sycamore.		
May 4 to May 14, ...	21	53·5	21	47·40	5·00
May 14 to May 24, ...	27	156	72	52·78	4·30
May 24 to June 3, ...	122	566	442	56·30	5·13
June 3 to June 13, ...	159	785	636	59·10	5·80
June 13 to June 23, ...	239	1,036	807	56·55	5·86
June 23 to July 23, ...	390·3	1,007	913·6	61·96	4·61
July 23 to Aug. 22, ...	588·3	850	933	62·13	2·10
Aug. 22 to Sept. 21, ...	591	716	896·3	53·90	4·97
Sept. 21 to Oct. 21, ...	465	80	638·3	49·21	2·21

The differences in weights and leaf areas of the plants experimented with are to be remembered when comparing the above figures. Thus, the plants in the order given above, weigh respectively 2 oz. 370 grains (1,330 grains), 4 oz. 40 grs. (1,960 grains), and 2 oz. 24 grs. (984 grains).

NOTE ON RELATIVE HUMIDITY.

It may be of interest to the reader to note the relations which subsist between the conditions mentioned on page 261, viz., the Dew-point, Relative Humidity, and other data usually set forth in the tables—Dry and Wet-bulb readings, Vapour Tension, and the actual amount of vapour in, say, each cubic foot of air. Various means have been devised for obtaining these data, but those now most used are the wet and dry bulb thermometers, read conjointly with Glaisher's Tables—a well-known and much used publication (*Hygrometrical Tables, adapted to the use of the Dry and Wet Bulb Thermometers*, by James Glaisher, F.R.S, Taylor and Francis, London). The vapour density, corresponding to every degree of temperature ordinarily experienced, has been carefully ascertained. The relations of the temperatures indicated by the dry and wet bulb thermometers, and that of the dew-point, have also been worked out and expressed in a formula arrived at by the late Dr. Apjohn, of Trinity College, Dublin. From this formula the readings of the thermometers, the dew-point and other data, may be obtained. Thus :—

If f be the vapour tension in the atmosphere, the condensation temperature corresponding to which is the dew point,

f', the vapour tension of saturated air, corresponding to the temperature indicated by the wet bulb reading, ascertained from Glaisher's Tables,

d, the difference between the readings of the two thermometers at the same time—t for the dry bulb and t' for the wet bulb. Then f is found for temperatures above 32° F. by the following contracted form of Apjohn's formula usually adopted, $f = f' - \frac{d}{87}$.

A hypothetical case will illustrate the use of the formula. Let the dry and wet bulb readings be respectively 60° and 55°, f' for 55° according to Glaisher is $\cdot 433$; $\frac{t-t'}{87} = \cdot 057$; therefore $f = \cdot 433 - \cdot 057 = \cdot 376$.

The temperature corresponding to this vapour density, as found by Glaisher, is nearly 51°, which represents the dew-point.

Now, air *saturated* at 60° has a vapour density of ·518 ; but the density of that which the air actually contains is ·376 ; then the relative Humidity is found by the statement :

$$\cdot 518 : \cdot 376 : : 100 = 72\cdot 6.$$

A cubic foot of air saturated at 60° contains 5·87 grains of aqueous vapour : the air supposed in our instance therefore contains 5·87 x 72·6÷100, or 4·26 grains per cubic foot. Hence this air is thus described :—

Dry bulb thermometer, 60° F. ; Wet bulb, 55° F. ;
Dew point, 51° F. ; vapour density, ·376 ;
Relative Humidity, 72·6 per cent. ; contains 4·26 grains watery vapour per cubic foot.

APPENDIX.

NOTES ON MODERN SOIL RESEARCH.

(a) Agricultural Maps.

FRANCE.—Agricultural maps have long been known in France. They were originally proposed and made by M. De Caumont of the Department of Calvados. M. Delesse subsequently prepared similar maps for the Department of Seine and Marne; and, more recently still, has been issued a *Carte Agronomique* of the district of Melun, adjoining the French capital on the south—the result of field and laboratory work carried out in 1898 and 1899. The map, which is produced on the one-fifty-thousandth scale (1¼ inch to the English mile), and covers an area of 1,065 square miles, has been made by M. P. Gustave Lefèvre, Agricultural Engineer, upon the basis of an enlargement of the geological map of the area, prepared by M. Gustave Dollfus under the superintendence of M. Michel Lévy, Director of the French Geological Survey. The information given on the latter is supplemented by observations on 250 soil samples, analysed—mechanically and chemically—by M. Lefèvre; and, besides serving its prime purpose, of supplying information as to differences noticeable in the soils of the area, and thus affording an intelligent basis of operations at the Experiment Station of Melun, the soil map also affords striking illustration of the bearing of geology upon those differences. The system of colouring in the sheets, adhering to the geological rather than to the merely physical distinctions, is not so intricate as the German or American soil maps, and seems well suited to educational purposes; there are only about a dozen colours with symbols used, and three additional symbolical indications. A description* accompanies the maps, from which the following quotations are drawn (p. 3):—" M. A. Carnot, who has so particularly interested himself in the development of Agricultural maps, permits us to recall here conclusions given in his account to the National Society of Agriculture." . . . . " We already know, by tillage observations, that which is necessary to be supplied to an earth of a given composition, to put it in a good state of fertility. The observations, increasing in number at present in every country, with uniform bases of comparison, will not fail to fix more definitely still, the influence of *the nature of the soil*, and that of the manure, upon the *quality* of the crops, in the different conditions of climate. Well made agricultural maps, by revealing to cultivators the composition of their soils, and enabling them in consequence to know what is lacking, and what is right to supply to them, to obtain the most satisfactory returns, will render assuredly much greater services than one can as yet suspect."

" Thus it is desirable that similar maps should be increased in number, and be encouraged by municipalities, associations, and specialists who wish to aid in the progress of agriculture in France."

Again (page 6) M. Lefèvre writes: " Besides the direct results which we enumerate, the *Carte Agronomique*, as remarked by M. Petermann,† will be a valuable source of information for all those who are occupied in agricultural teaching, for Directors of Experiment Stations, for Professors of Agriculture, for State Agriculturists, for Agricultural Engineers, and I shall add advisedly for Instructors. It will be the principal Document of comparative agriculture."

GERMANY.—Turning to the work of soil-investigation and soil-mapping in the German Empire, one finds ample precedent for work of the kind in connection with agriculture. Observations upon geological facts and soil conditions have been concurrently carried on during the past thirty years or more under the superintendence of Dr. Keilhack, of the Prussian Geological Survey. Maps (*geologisch-agronomischen Specialkarten*) and descriptions of some 30,000 sq. miles have been published, and those of 15,000 square miles are in progress, making in all 43,000 square miles of the North German Plain. The investigations involve the making of auger borings up to two metres (say 6 feet 6 inches in depth), and to the number, in various maps, of from 1,000 to 5,000 in 50 square miles, *i.e.*, up to 100 per square mile; the examination of soil, subsoil, and deeper layers; collection of special samples; and the mechanical and chemical examination of samples in the laboratory. The data thus ascertained are set forth on elaborate colour-printed maps planned on the scale of about 2¼ inches to the mile, and divided into sheets which are nearly square, and of such a size that sixty lie within one degree of latitude, and one of longitude. They thus measure about 18 inches by 17¼ inches.

---

* Notice sur la Carte Agronomique de Melun, by P. Gustave Lefèvre, Ingénieur Agronome.

† Director of the Royal Experiment Station at Gembloux, Belgium.

The colouring of the maps is planned to represent the geological distribution of soil-forming materials—the subsoils—while the nature of the soil and subsoil, and their depths are indicated by letters and figures on the maps where samples have been taken. The system of colouring and indications by lettering are intricate. On the Berlin sheets, for example, the colours and symbols number twenty; what they severally import is described by marginal reference tablets; and, accompanying the explanations, are descriptions of the sub-soils, and their conditions, which are generalized in vertical sections (*Bodenprofile*), showing eight additional symbols and colours.

The facts ascertained in the borings (*Bohrungen*) are set forth in *Bohrregisters*, supplied with maps indicating where the borings were made (*Bohrkarten*). These accompany the coloured maps; and the sets of coloured maps, uncoloured reference maps, and descriptions, are supplied gratis to all Universities, and to technical, agricultural, and forestry schools. 1,500 copies of Dr. Keilhack's General Explanation of these maps have been freely distributed throughout the portions of the country which have been traversed; and, further to awaken and promote enquiry which the information on these maps is intended to meet, four-week courses of instruction in mapping are arranged for, and given by members of the Geological Survey to agricultural teachers.

The methods adopted and advantages aimed at, in this work, are stated in the general explanation of the maps mentioned, from which the following brief extracts are taken:—" The explanation accompanying each coloured map, contains a geological and an agricultural part. In the latter the weathering process and nature of the several soils are described. These are divided into groups according to the chief soil components, and are, loamy, sandy, clayey, humous, calcareous," &c. The same part of the explanation tells how the soil was formed out of the several unweathered rocks (species), the agricultural notes on the maps are explained by typical sections; the importance of the subsoil conditions, represented in the map, is pointed out, suggestions of desirable improvements are offered, defects in the methods of treatment or employment of the soils are shown, disadvantageous cultivation discussed, information as to the depth to which decalcification of the soil has proceeded is collected, and finally the natural means of amelioration presented in the sheet is mentioned. In the analytical part of the explanation, a set of chemical and mechanical analyses of the most important types of rock and earth is given for each respective sheet.

This is followed by an account of the deposits serviceable in agriculture. " In the first rank come into consideration the profitable calcareous formations, such as marl in its widest signification," and, in consequence, their presence and distribution receive prominent representation on the maps. In the case of commonly occurring clay-soils the terms and indications are as in the following example:—

Ackerkrume (Soil)	L.S. 2·5 (Loamy sand, 2·5 decimetres, 10 inches).
Over *Urkrume* (Subsoil) . . .	S.L. 3·5 (Sandy loam, 3·5 decimetres, 14 inches).
Over *Untergrund* (Deeper Subsoil) .	S.M. 6 (Sandy marl, 6 decimetres, 24 inches).
Over *Tiefer Untergrund* . . .	T. 4 (Clay greater than 4 decimetres).

AMERICA.—In the United States similar ample measures are being taken to supply the agriculturist with a knowledge of his soil. So important has this work come to be regarded in the States, that a special Bureau for soil-investigation and mapping, distinct from the Geological Survey, has been constituted within the last few years, with Dr. Milton Whitney as Chief; and its popularity may be gauged by the fact that Congress increased the grant for it, in 1900, from 30,000 to 109,000 dollars (£6,000 to £22,000). Up to 1901 over 5,000 square miles have been surveyed, chiefly in the saline land of the Western States, and some in the tobacco-growing lands of Massachusetts and Connecticut.

The maps issued by this Bureau, on the scale of one inch to the mile, and contoured at 20 feet intervals, are models of work, and the result of close investigation. Both in the field and in the laboratory the physical conditions of the soil, and of their chemical components, are made the subjects of enquiry. The topographical maps of the Geological Survey are used where available; and, in his Report for 1899, Mr. Whitney writes as follows (page 15):—" Wherever it has been possible it has been the policy of the Division to work in close cooperation with the State Experiment Stations, the State Geological Surveys, Boards of Agriculture, or other local institutions." Again, on page 30:—" In the field classification of soils, all features are taken into consideration which appear in any way to influence the relation of soils to crops. The classification is based mainly upon the physical propertits and conditions of the soil, as determined by the soil expert; but it is not based solely upon this. Any chemical features, such as deposits of marl, or highly calcareous soils, or of highly coloured soils, are considered, as well as the character of the native vegetation and the condition of the crops. Local variations in the character of the soil, of less than one-fourth of a mile in extent, are generally ignored, unless their variation constitutes a very prominent feature."

Professor Whitney further explains (page 31):—"No attempt is made to correlate loams in different valleys, unless the two are very clearly identical, in origin, in character in relation to crops, and under essentially the same climatic conditions. If there is any apparent difference it is preferable to give each a local name, and describe each separately in the most careful and exhaustive manner."

The intricacy of colouring and symbols in the German maps has already been noticed, and it will be inferred from the character of detail just described that on the American maps also are found differences of indications by colouring, which, for purposes of instruction, many would deem superfluous; but in the case of specialised cultivation, such as that of plants grown for flavour or aroma, *e.g.*, the various types of tobacco—minute differences in the physical conditions of the soil, well justify a highly detailed system of map representation. In addition to the field-work of the Soil Survey, exhaustive laboratory research concurrently proceeds, both in the chemical examination of soils, and in the discussion of physical and physico-chemical phenomena.

A well-known authority, in an article to which allusion has already been made, has recently stated that* "Science helps practical farming in ways as varied as they are innumerable, lessening the risks and multiplying the resources of the farmer": and the value of soil research has been recognised, since Liebig worked out † the principles of modern Agriculture in his laboratory at Giessen, and enunciated them in 1840; yet, unfortunately, all are not agreed as to the extent to which laboratory work may usefully be carried. Happily for both science and agriculture, Americans are not disposed to confine such enquiry within narrow bounds; and the popularity of the work has already been alluded to.‡

In the Report for 1900 issued in the Spring of 1901, Dr. Whitney states that at least twenty Survey parties were to have been at work in different States in the summer of 1900, and a still greater number have been asked for, than it was possible to send out. Seven hundred and fourteen samples were added to the collection of soils, making 4,758 samples in all, up to the end of 1900. Two hundred and sixty soil analyses were made in that year; and photographic negatives appertaining to the work of the Division, to the number of 455, had been arranged and catalogued.

Such information as that collected by the Division is doubtless of special value in a new country; though it is remarkable that the necessity for it was not realized until recent years, that is to say, when this application of science to farming rendered manifest the want, whilst meeting it. But it is not only in a new country that the application of this branch of science to Agriculture is valued, and seen to be necessary, by those who hold themselves responsible for the promotion of the Industry. What has been said of the work in France and Germany shows this. The same may be said of a much less important country than either, viz., Belgium.

* Roland E. Prothero, M.A., M.V.O., in his article "English Agriculture in the reign of Queen Victoria," *Jour Roy. Agri. Soc.*, Vol. 62, p. 21.

† In his work "Chemistry in its Application to Agriculture and Physiology."

‡ As regards Agricultural Education, a writer who is interested in the subject has recently informed readers of the "Irish Farmers' Gazette," that in America "there are 65 Agricultural Colleges and 57 Agricultural Experiment Stations, the total income of which, in 1900, was over 1½ millions sterling. Some forty years ago, grants of land were made at the rate of about 30,000 acres for every Senator and Member of Congress returned at the time the Act was passed. A dozen years ago an additional grant of £5,000 a year was made, while £3,000 had previously been voted to each Experiment Station, which is usually connected with a College. Apart from these, large sums are granted by the different States for building, equipment, and other purposes, with the result that already 41,000 students have graduated—the number of graduates in 1900 having been 3,114, of whom a very large proportion were agricultural students pure and simple. In the same year the agricultural students numbered 5,066, and ordinary students 3,114. In most cases these students obtain tuition without the payment of a shilling, so that a young man may pass his four years at a State College and obtain his degree at an entire cost of some 14*s.* to 21*s.* a week to cover his board and lodging, or if he is of a careful and practical turn of mind he may almost extinguish even this sum by obtaining a scholarship, and earning money by devoting some portion of his time to practical work upon the College farm. . . . .

"A year ago, the value of the permanent equipment and funds of the various Colleges in the United States was estimated at 11¾ millions, while in the same year the additions to the permanent endowments and equipment reached £680,000.

"American Agriculture is practically controlled by the Agricultural Department, the Minister of Agriculture being an old Professor at one of the State Colleges. The Department is centralised in the capital city of Washington, and it possesses a large number of departments, dealing with soils, live stock, botany, chemistry," and so forth.

BELGIUM.—This country with an area of 11,000 square miles—one-third the size of Ireland—and a population of six millions (that of Ireland being four and a half millions), has its *Carte Agronomique* and its Agricultural Institute and Experiment Station at Gembloux, attended by over 100 students. A farm of 150 acres is set apart for field operations, and in connection with it are laboratories, where the examination of soils is one of the branches of study, under the Directorship of Professor Petermann.

The Institution (*L'Institut Chimique et Bactériologique de l'Etat*) has issued over seventy bulletins on various topics, amongst which are the results of analyses of Belgian soils. And Professor Petermann has himself published a three-volume work on Agricultural Research (*Récherches de Chimie et de Physiologie Appliquées à l'Agriculture*). The third volume of 426 pages has the following Table of Contents :—

L'Exploration chimique du sol belge dans ses rélations avec la Carte Agronomique—L'analyse du sol—Méthode suivie à la Station Agronomique de Gembloux—Analyses complètes de sols belges—Analyses de minéraux—Résumé et discussion.

SOIL RESEARCH IN THE BRITISH ISLES.

THE GEOLOGICAL SURVEY.

The work of the Geological Survey, particularly the detailed mapping of the superficial deposits, affords an excellent basis for soil maps. The main object has been to distinguish, and present separately, the chief divisions of the glacial drifts—Boulder-clay, and Sands and Gravels; but in doing this, the superficial deposits of the southern part of England, where probably no drift exists, have also been mapped showing the characters which the subsoils derived from the different underlying geological Formations assume, as well as the alluvial deposits. The prevailing nature of the contents of the Drift is however not stated.

The corresponding Survey, commenced in Ireland in 1901, in charge of Mr. Lamplugh, F.R.S., and under the Directorship of Dr. Teall, M.A., F.R.S., &c., distinguished, in the Dublin area,

Peat and Alluvium,
Blown Sand,
Raised Beach,
Old River Deposits,
Fluvio-glacial deposits,
Glacial Sands and Gravels,
Boulder-clay containing much limestone,
Boulder-clay containing little limestone.

Thus the maps showing these deposits indicate the prevailing contents of the boulder-clays, and the general character of soil formed from each deposit; a description accompanies each map, which besides giving an account of the above scientific divisions of the superficial covering, also contains descriptions of the solid rock, accounts of mines, minerals, and quarries, and agricultural notes on the various types of soil in the district. The information was obtained in all available natural and artificial sections—in stream and river banks, road cuttings, ditches, quarries, &c.—and in shallow borings when special information, as for the agricultural notes, is necessary; and examination of the soils and subsoils was carried out in the laboratory by the writer. The districts around Belfast, Cork, and Limerick have since been surveyed and described, on the same general plan.

ROTHAMSTED.—Sufficient justification for reference to the work at Rothamsted may be found in the fact that field experiments are, by many, given a large place as a means of soil diagnosis; to some, indeed, field experiments are the only practical means necessary and adequate for the purpose; but the Rothamsted authorities view the matter differently. In the third course of American Lectures, arranged for under the "Lawes' Agricultural Trust," and undertaken by Dr. Dyer in the autumn of 1900, the soils and subsoils of Rothamsted formed the subject. Throughout the sixty years of these experiments samples have, from time to time, been collected, examined and stored, until the collection in 1901 numbered thousands of samples which are placed in a new wing of the Laboratory built to contain them. A view of this is here shown.

The lectures are based upon mechanical and chemical analyses of the soils, some made in Dr. Dyer's own laboratory, and some at Rothamsted. The chemical analyses bear chiefly upon the exhaustion of fertilising substances in the soil by cropping and drainage, but also upon the amounts of the leading fertilisers, viz., nitrogen, phosphoric acid, potash, and lime, present in the soil at Rothamsted under various conditions of treatment. Such data furnish a sound basis of comparison of the soil of this standard locality with the soils of other places ; and it is difficult to perceive how the volume of information, collected throughout the half century's Field Experiments at Rothamsted, can logically be applied elsewhere, for either scientific or economic ends, unless reliable means of comparing of the soils are forthcoming, and the details of comparison kept fully in view.

Figs. 64, 65. VIEWS OF ROTHAMSTED LABORATORY.

(From Photographs by J. R. Kilroe.)

First View (left side), Part of Store-room, showing collection of Soil and Subsoil Samples; Sampling Irons (⊕); and the maul (×), with which they are driven down into the earth.

Second View (right side), Part of Central Hall, showing collection of plant ashes, &c., in sample bottles; canvas sheet (⊕) with portion of Table, setting forth results of experiments upon the appropriation and waste of Nitrogen in soils; and large scale Photographs (×) representing results of Turnip growing, and the Root systems of Leguminous Plants — peas and sainfoin—in experiments conducted in 1900.

RAIN-GAUGES.—Amongst the many lines of inquiry pursued at Rothamsted none are more valuable than those of the amounts and contents of drainage waters. As a basis of investigation the amounts of rainfall, percolation, and evaporation, as indicated by and deduced from the readings of rain-gauges, have had to be studied concurrently with the field experiments. For this purpose rain-gauges were constructed in 1870 in such a manner as to leave the soil and subsoil of 20 in. 40 in. and 60 in. depths in their exact original position ; the gauges were built around, and propped beneath, without moving the soil. The amount of percolation therefore may be taken as indicative of what proceeds elsewhere in the experimental area. The following Table gives the results of observations over a period of many years.

RAINFALL AND DRAINAGE AT ROTHAMSTED.

NUMERICAL SUMMARY OF RESULTS.

HARVEST-YEARS. September 1 to August 31.	RAINFALL.		DRAINAGE.			DIFFERENCE* evaporated (or retained by soil.)			LOSS OF NITROGEN PER ACRE IN DRAINAGE. Reckoned as Nitrogen.		
	5-inch Funnel Guage.	$\frac{1}{1000}$th Acre Gauge.	Soil 20 ins. deep.	Soil 40 ins. deep.	Soil 60 ins. deep.	Soil 20 ins. deep.	Soil 40 ins. deep.	Soil 60 ins. deep.	Soil 20 ins. deep.	Soil 40 ins. deep.	Soil 60 ins. deep.
AVERAGES FOR EACH MONTH. 20 HARVEST-YEARS, 1877–8 TO 1896–7.											
	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	lb.	lb.	lb.
September, ...	2·53	2·63	1·04	1·02	0·95	1·59	1·61	1·68	3·91	2·73	2·60
October, ...	3·29	3·38	2·07	2·09	1·93	1·31	1·29	1·45	6·38	5·00	5·04
November, ...	3·05	3·14	2·41	2·51	2·37	0·73	0·63	0·77	6·30	5·66	5·86
December, ...	2·32	2·42	1·95	2·10	1·98	0·47	0·32	0·44	3·68	3·91	4·36
January, ...	1·91	2·04	1·67	1·88	1·82	0·37	0·16	0·22	2·57	2·81	3·40
February, ...	1·87	1·95	1·55	1·71	1·58	0·40	0·24	0·37	2·46	2·51	3·00
March, ...	1·77	1·88	1·00	1·15	1·08	0·88	0·73	0·80	1·48	1·67	2·00
April, ...	1·82	1·89	0·52	0·58	0·53	1·37	1·31	1·36	0·98	0·95	1·17
May, ...	2·11	2·17	0·58	0·65	0·57	1·59	1·52	1·60	1·13	1·04	1·19
June, ...	2·26	2·33	0·61	0·65	0·61	1·72	1·68	1·72	1·24	1·09	1·25
July, ...	2·73	2·80	0·73	0·74	0·69	2·07	2·06	2·11	2·07	1·53	1·69
August, ...	2·84	2·94	0·87	0·86	0·79	2·07	2·08	2·15	2·87	1·93	2·22

*Calculated on the Rainfall shown by the $\frac{1}{1000}$th acre gauge.

SOIL RESEARCH ELSEWHERE IN ENGLAND.—Work of this character is now being done in District and County Agricultural Colleges and Laboratories; and supplies much valuable information, especially when it is carried on concurrently with field experiments. The scheme adopted at the Oxford University Extension College at Reading furnishes an instance of the work referred to. Twenty analyses of the Dorset soils, experimented upon by the College, are carried out yearly at the laboratory and supplied to the County Council in return for a contribution of £175 to the College funds. Farmers supply samples free, except for the cost of transmission, and the expense attaching to skilled direction as to where the samples are to be obtained.

For many years past, similar work has been in progress in connection with Wye College, and was under the supervision of Prof. A. D. Hall, M.A., now Director at Rothamsted Station. It was undertaken at the request of the County Councils of Kent and Surrey. Different types of soils were selected, their boundaries traced in the field, and the variations noted within their limits. In his Report, Prof. Hall gave it as his opinion that the best method of classification is to group the soils "according to the rock which underlies them." The same authority, in a paper read to the Farmers' Club in December, 1902, urged the advisability of publishing a series of Drift Maps on the scale of six inches to a mile, the work of which could be "supplemented by soil surveys and analyses executed by local agricultural colleges, and research institutions until every farmer could be put in possession of that exact knowledge of the soil, which is fundamental for all farming operations." Such systematic examinations of soils and subsoils are made in the laboratories and institutions mentioned in the footnote,* and they have recently been, or are about to be, undertaken in the West of Scotland Agricultural College, the University College of Wales, and in Uckfield College.†

---

* *See* next page.

† As the writer has been informed by Professors R. Patrick Wright, S. Allan Murray, and S. A. Woodhead.

To secure uniformity of work, and in the statements of results, a consultative committee[*] interested in Agricultural Education was elected, who formulated rules of procedure. If the collection and examination of soil and subsoil samples were extensively and systematically carried out, and treated as supplementary to the data collected by the Government Geological Survey, the results, like these data, being represented on maps[†] for publication, accompanied by written descriptions, the records would form a valuable contribution to the economic assets of the United Kingdom.

SAMPLING SOILS AND SUBSOILS.

As will be seen from these notes the methods of sampling are exceedingly various and are somewhat liable to mislead when comparing descriptions of those treated at different places. Thus at Rothamsted—"Sampling Irons"[‡] have been used by Lawes and Gilbert; and are shown in the photograph on page 283, as also the maul with which the "irons" are driven into the earth. They are of two sizes—9 inches by 9 inches by 9 inches, and 6 inches by 6 inches by 9 inches, internal measurements. Made of steel, their lower ends have sharp edges, and their upper, thick and blunt rims, to receive the blows of the maul. In sampling, the vegetation is closely shorn off, and the implement driven down to its full depth of 9 inches, the standard depth for soil in vogue at Rothamsted from the commencement; the surrounding earth is then dug away and the prism of earth enclosed is cut off beneath, raised and taken out of its mould. The ground thus cleared forms a second platform upon which the operation is repeated to obtain a sample of the immediate subsoil, and so on for greater depths.

More recently another size of sampling iron has been used, made for obtaining samples of the soil and subsoil to send to Germany. The dimensions of this "iron" are such as form earth cubes one-fifth of a metre in size. The depth, a trifle less than eight inches, accords with what the late Sir J. Henry Gilbert would adopt as arbitrary standard for soil in contrast to subsoil, instead of 9 inches.

Woburn, Reading, &c.—The method adopted by the Royal Agricultural Society is as follows:—The spot being selected, digging is performed around it so as to leave a prism of earth standing, which when accurately trimmed to 6 inches square and 9 to 12 inches in depth, according to the depth of the soil, a box of corresponding size is slipped down over the prism and this removed. The subsoil is similarly sampled. Sampling is sometimes done with the sampling irons, similar to those used at Rothamsted, which seem best suited to the case of all light sandy soils. At Reading College the practice adopted is that of the Royal Agricultural Society. No arbitrary standard for soil is used, but the sample box, containing the prism of earth, being 18 inches in depth, and made so that one side is easily removable by unscrewing, the change from soil to subsoil can be seen and noted. It is generally found to be very gradual in the case of old leas, and sharply defined in tilled land.

America.—Bulletin No. 16 of the Division of Soils, issued in 1899, is a catalogue of the first four thousand samples in the soil collection. Besides giving references to the numerous localities scattered throughout the States where the soils and subsoils were obtained, and the basis upon which these are classified, accurate instructions are set down by the Chief of the Division for procuring samples, as follows (p. 14):—"To collect the samples with a spade—remove all grass, leaves, and litter, and dig a hole, like a post-hole, 24 inches deep. Scrape the sides clean, and notice the depth at which the change of colour occurs between the soil and subsoil. Take a sample above this by cutting off the slice of soil 3 or 4 inches thick down to the change of colour, and mixing this thoroughly together. Fill a cloth sack with this well-mixed soil, tie it securely, and label it, &c. Then clean out the hole again and scrape the sides so as to get rid of every particle of the top soil, and take a sample of the subsoil from immediately below the top soil to a depth of at least 24 inches. Put this sample in a separate sack, tie it securely and label it.

---

[*] In France, too, a similar provision has been adopted in the appointment of the *Comité Consultatif des Stations Agronomiques et des Laboratoires Agricoles.* The English Committee was chosen by the Agricultural Education Association, and consisted of T. S. Dymond, of the Essex County Laboratories; M. J. R. Dunstan, University College, Nottingham; C. M. Luxmoore, Reading College; T. B. Wood, Cambridge University, Agricultural Department; and D. A. Hall, South-Eastern Agricultural College, Wye.

[†] A gentleman attached to a celebrated English Experiment Station, and in charge of one of the first agricultural laboratories in the world, some time since expressed, in a letter to the writer, the following opinion:—"I quite agree as to the utility of soil-maps. I have for a long time thought that agricultural geology deserves a good deal more attention than it gets in this country. In addition to the knowledge of the geological origin of soils, I think that complete physical and chemical analyses of a carefully selected number of typical soils would be very useful. In the case of old grass lands, I would suggest that botanical analyses of the herbage might be made."

[‡] The Rothamsted irons described by Wiley measure 10 ins. by 12 ins. by 9 ins. (deep)—p. 80 of his work.

If there is no apparent difference between the soil and the subsoil, take a sample of the soil nevertheless, to a depth of 6 inches from the surface, and a sample of the subsoil from below this to a depth of 24 inches, and put them into separate sacks as above. If the character of the subsoil materially changes before the depth of 24 inches is reached, a separate sample of this changed material should be taken and the depth noted at which the change occurs." In lighter soils the subsoil is sometimes sampled to a depth of 30 inches. Eight to ten pounds of material should be collected and put in sacks 14 inches by 8½ inches, when the spade is used; sacks 8½ inches by 6 inches, and 6 inches by 4 inches, are used when samples are taken with the auger.

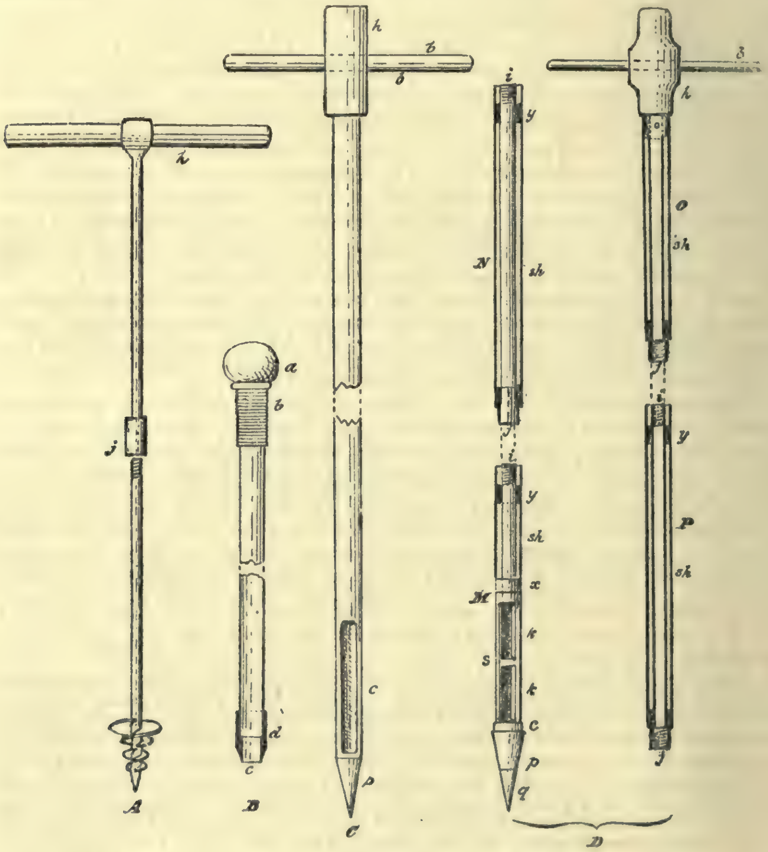


Fig. 76. *A.* Earth auger; *h*, removable handle; *j*, joint.

B. Soil sampler, as used by King; *a*, handle; *b*, coiled brass wire; *c*, steel cutter soldered inside brass tube, 1⅜-inch dia.; *d*, outer belt, for strength and to give room for easier play of instrument in hole.

C. Boring rod used on the Prussian Soil Survey; *h*, head for receiving blows of maul; *b*, handle; *c*, sample cavity; *p*, boring point.

D. Jointed boring rod. *h*, *b*, *p*, as above; *h*, *p*, of brass; *q*, steel point; *i*, *j*, joints of rod sections, *M*, *N*, *O*, *P*; *sn*, sheath of brass tubing 1½-inch dia.; *y*, *y*, bearings for sheath, fastened to gun barrel within; *k*, socket, free on brass casting with cavities and carrying knives to scrape off samples at any required depth, depositing the material in cavities at *s*; *x*, *y*, removable part of sheath.

THE AUGER.—Sampling with the spade is not suited to rapid traverses. In consequence of this, augers are employed for the purpose, the use of which is admitted by the English Consultative Committee, as it is also in America for mapping. The drawback of this method is that it does not give the due proportion of stones in soil samples: but this is insignificant when expense has to be considered, and in view of the necessity of obtaining information concerning the deeper subsoils. Dr. Luxmoore called attention to a point which illustrates this, viz.:—On

Geological maps we do not represent the thickness of the various layers of sand, clay, &c., in mapping; and if these layers are sharply defined, as they sometimes are, samples collected only 18 inches in depth, with the spade, may in many cases give no clue to the conditions for the important problems of drainage. Again, the subsoil at 2 feet 6 inches in depth may be rich in lime salts, and that at half that depth may be utterly devoid of carbonate of lime, may contain less than even the soil, as indeed are the exact circumstances at the unmanured plot, and more than probably at other points, at the Albert Farm, Glasnevin. The decaying organic matter forming humic and nitric acids operates powerfully on the immediate subsoil; and, getting saturated before descending further, loses its effect upon the deeper layers. The finest matter in the deep subsoils is rich in calcareous matter —it is in fact a rich marl, and is revealed by the auger. The auger in use by the writer for several years is shown as No. 1 (A) in the accompanying illustrations (C) is a view of the auger used on the Prussian Geological Survey for deeper borings. With this instrument, Dr. Keilhack states, samples can be taken at the rate of 20 per hour—which must be regarded as a very high rate of work. This auger seems so liable to get caught in stony soils, by pebbles falling into the boring after the head, that the writer has designed the auger No. 4 (D).* Its construction is as follows :—A steel point set in a brass socket, gun-barrel joints screwed together, and a brass head with cross bar. It carries brass sheath-tubing, to guard against the instrument's sticking fast in the hole, and add to its strength. A slot is cut in the lowest portion of the tube, and steel knives are set along the slot, so that, when the instrument is turned, the knives detach the soil at any depth required, and fill the brass socket with the sample. To prevent earth falling into the socket while the auger is driven downward, the cutting part covers the cavity until the rod is turned. The turning first opens the cavity, and then fills it. Another instrument recommended by Hilgard is also shown No. 2 (B). It is useful in obtaining specimens of soils, for the estimation of the air spaces. It is difficult to work with on heavy clays, but convenient for sampling light soils.

MECHANICAL ANALYSES.

It would be impossible here to attempt an account of the numerous methods which are in vogue for separating the clay, silt, sand, and gravel in soils: though, as shown in the first Chapter, so very much depends upon the way in which these commingle in the soil, that the subject has received much attention. The reader who wishes to look particularly into it may consult Wiley's "Principles and Practice of Agricultural Analysis," vol. I., and Professor King's work, "The Physics of Agriculture." The methods are of two kinds, viz., decantation, by allowing the sand and silt to settle to the bottom of a vessel, and repeatedly pouring off the clay-charged water; and by washing with a weak current of water which ascends vertically in a high cylindrical vessel carrying off the clay, and leaving the silt, sand, and gravel. Both methods are based upon the different hydraulic values of particles of sand and different sized particles of clay. In his description of Schöné's method of elutriation, Wiley gives the relations between the heights of the columns of water in the supplying piezometer, the velocity in the elutriating cylinder of 4·489 c.m. diameter, and the diameters of the silt particles affected by the current. The following figures are taken from his Table :—

Height of Column in Piezometer. Centimetres.	Velocities in elutriating cylinder 4·489 c.m. dia. (Millimetres per second).		Corresponding Diameter of Silt Particles. Millimetres.
	Observed.	Calculated.	
1·5	0·222	0·220	0·0120
2·0	0·346	0·355	0·0162
3·0	0·531	0·530	0·0210
4·0	0·650	0·660	0·0236
5·0	0·751	0·769	0·0265
6·0	0·850	0·864	0·0285
8·0	1·050	1·028	0·0320
10·0	1·170	1·169	0·0347
20·0	1·730	1·710	0·0441
30·0	2·100	2·110	0·0506
40·0	2·460	2·450	0·0556
50·0	2·770	2·750	0·0598
70·0	3·290	3·270	0·0667
100·0	3·870	3·920	0·0749

---

* Nos. 2 and 4 were made by Messrs. Edmundson and Co. of Dublin, under the direction of the writer.

A Table is here given also drawn from Wiley's work (Vol. i., p. 249), exhibiting the extent to which grading of soil components is carried in American soil-research, the application of conventional terms adopted, the approximate dimensions of the particles of each grade, and the proportions in which gravel, sand, silt, and clay occur in a few samples.

Results of Mechanical Analyses of some American Soils :—

Diameter of Particles in Millimetres.	Conventional Names.	Early Truck.	Tobacco Soils.	Wheat Soils.	Grass and Wheat.	Lime-stone Soils.
2 —1	Fine Gravel, ...	0·49	1·53	0·00	0·00	1·34
1 —0·05	Coarse Sand, ...	4·96	5·67	0·40	0·23	0·33
0·5 —0·25	Medium Sand, ...	40·19	13·25	0·57	1·29	1·08
0·25 —0·1	Fine Sand, ...	27·59	8·39	22·64	4·03	1·02
0·1 —0·05	Very fine Sand, ...	12·10	14·95	30·55	11·57	6·94
0·05 —0·01	Silt, ...	7·74	28·86	13·98	38·97	29·05
0·01 —0·005	Fine Silt, ...	2·23	7·84	4·08	8·84	11·03
0·005—0·0001	Clay, ...	4·40	14·55	21·98	32·70	43·44
		99·70	95·04	94·20	97·63	94·23
Org. matter, water and loss, ...		0·30	4·96	5·80	2·37	5·77

CENTRIFUGAL METHOD.

Decantation and elutriation are extremely tedious processes; and when, as in survey work, large series of soils have to be treated in a limited time, in the laboratory, more rapid methods have to be resorted to. A method has been devised by Dr. Whitney, in which centrifugal action is used to precipitate from fluid mixtures in test tubes the coarser particles, leaving in repeated operations successive grades of finer particles suspended in water, which are obtained by filtering and estimated. The quantity of mixed earth which can thus be dealt with is 10 grams, and the desire to obtain a larger quantity of coarser material than is finally left for treatment with sieves has led the writer, in examining soils for the Geological Survey, to devise a means of separating sands from fine silts and clay in one operation. This method has been described in detail in a paper read before the Royal Dublin Society, January 19th, 1904.*

The apparatus consists chiefly of a centrifugal table, upon which are secured two flasks with different samples—about 25 grams mixed with water. To the neck of each flask is attached a glass tube ½-in. diameter, and 4 inches in length. On the table the tubes point outward, and the bulbs inward, a sheath of tin having been slipped down over the tube and neck of each flask before placing it on its rest. When the table is rotated for 1½ minutes at 900 rotations per minute the sand and coarser silt are thrown to the outer ends, and become sufficiently consolidated in the tubes to admit of their being removed from the flasks, while the finest silt and clay remain in the bulbs as aqueous mixtures. The cores are withdrawn from the tubes, placed on drying-trays, and either weighed in bulk, or graded by means of sieves. Separations of sands and silts down to ·1 m.m. diameter are thus obtained; for the separation of clays and finer silts from the aqueous mixtures remaining in the flasks, Whitney's method is adopted.

A valuable Paper on the mechanical analysis of soils† was read June 21st the same year, 1904, by Mr. T. Crook, A.R.C.S.I., the chief object of which was to describe a special improved form of Schöne's elutriating apparatus designed by the author, in use at the Royal College of Science. To the description are appended notes on a scheme for the mechanical analysis of a soil.

---

[*] Econ. Proc. Roy. Dub. Soc., 1904, I. (v.), 223.
[†] Do. do. do. do. 267.

AUTHORITIES CITED.

A

Page

Abercromby, Hon. Ralph, 259
Adams, Prof. Leith, 190
Aher, David, 159
Ansted, "Physical Geography," 254
Apjohn, Dr., 278

B

Bailey, Mr., 240
Barrett, Prof. W. F., F.R.S., 182
Bauerman, "Metallurgy," 158
Beaumont, Elie de, 31
Boate, Dr. Gerard, 163
Bonney, Prof., F.R.S., 129, 192
Braithwaite, Prof. Robert, 155
British Association, Proceedings of, 235
Buchan, Alex., M.A., 253
Bunsen, 27

C

Cameron, Sir Chas., 176
Carpenter, Prof. G. H., B.S.c., 192
Caumont, M. de, 33, 279
Clark, Dr., Soap Test for Water Hardness, 78
Clarke and Hildebrand, 89
Claye, M. Durand, 126
Close, Rev. Maxwell, M.A.., M.R.I.A., 141, 149, 228
Cole, Prof. Grenville A., F.G.S., M.R.I.A., 192, 193
Collins, 112
Crookes and Röhrig, 157, 158

D

Daily Telegraph, 159
Davy, M. Marié, 245, 254
Dawkins, Prof. Boyd, F.G.S., 194, 196
Delesse, M., 279
Dewar, Prof. Jas., F.R.S., 128, 177
Dollfus, M. Gustave, 279
Draper, Prof., 254
Dyer, Dr. Bernard, 282

E

Elsden, J. V., B.Sc. (Lond.), "Applied Geology," 160

F

Page.

Farmers' Gazette, ... 90, 154, 163
Fisher, Prof. W. R., B.A., ... 169, 170
Fitzsimon, Mr., ... 170
Forbes, Prof. Edward, ... 192, 194
Fouqué and Lévy, ... 28, 29
Frankland, Dr. Percy F., F.R.S., ... 175, 177
Fream, Dr., ... 34, 57, 84
Freeman's Journal, ... 163

G

Gages, Alphonzo, ... 2
Gardner, J. Starkie, F.L.S., G.S., ... 110
Gasparin, M. de, ... 13
Geikie, Sir A., LL.D., D.C.L., F.R.S., ... 95, 115, 121, 153, 154, 191, 196
Geikie, Dr. Jas., F.R.S., ... 134, 137, 141, 189, 191, 196
Gilbert, Sir Joseph Henry, F.R.S., 14, 89, 285
Glaisher, Jas., F.R.S., ... 258, 278
Grandeau, M., ... 57, 158
Green, Prof. A. H., M.A., F.G.S., ... 84
Griffith, Sir R., ... 133, 235, 246

H

Hall, Prof. A.D., M.A.. ... ... 284, 285
Hardman, Mr. E. T., ... 207
Hartley, Prof. W. Noel, F.R.S., ... 25, 177
Harty, Mr. Spencer, ... 176
Haughton, Dr., F.R.S., ... 120
Hensman, Miss, ... 5
Hodges, Dr. John F., ... 88
Hill, Lord George, ... 6
Hull, Prof. E., M.A., F.R.S., ... 81, 94, 98, 103, 110, 136, 137, 139, 141, 148, 189, 228

I

Ireland, Industrial and Agricultural, ... 47, 96, 135

J

Johnson, Prof. Thos., D.Sc., F.L.S., ... 5, 156
Johnston's Elements of Agricultural Chemistry, ... 31
Journal of the Chemical Society, ... 16
Journal of the Geological Society, ... 63, 98, 110, 137, 178
Journal of the Royal Agricultural Society, ... 281
Journal of the Royal Geological Society, Ireland, ... 228
Joyce, Dr., ... 190
Jukes, Prof,. M.A., F.R.S., ... 84, 98, 225, 238

K

	Page.
Kane, Sir R., ...	2, 35, 87, 157,
Keilhack, Dr., ...	280, 287
Kendall, Prof., F.G.S., ...	98
Kilroe, J. R., ...	37, 137
Kinahan, Geo. H., M.R.I.A., ...	4, 6, 112, 113, 148, 154, 161, 163, 164, 193, 217
King, Prof. F. H., ...	252, 287
"Knowledge,"	193
Knowles, Mr., ...	197

L

Lamplugh, Mr. Geo. W., F.R.S., F.G.S., ...	98, 193, 282
Lawes and Gilbert, ...	14, 285
Lawes, Sir J. Bennett, Bart., F.R.S., ...	89, 277
Lefevre, M. P. Gustave, ...	279
Leplay, M. A., "Géologie Agricole,"	117
Lévy, M. Michel, ...	28, 29, 279
Ley, Clement, Rev., ...	254, 255, 257
Lloyd, Dr., ...	259
Loomis, Prof., ...	254
Loughton, Mr. John Knox, M.A., F.R.A.S., ...	241
Luxmoore, Dr. C. M., ...	285, 286
Lyell, Sir Chas., Bart., F.R.S., ...	192

M

Marsh, Prof., ...	241
Matthews, J. W., M.D., ...	129
Maury, Capt., ...	258
M'Connell, Primrose, ...	242
M'Henry, Mr. Alex., M.R.I.A., ...	6, 94, 126
Miller, N. H. I., Ph.D., ...	18
Moore, Sir J. W., M.D., ...	245, 249, 260
Moss, R. I., F.C.S., F.I.C., Analyses by, ...	5
Muff, H.B., B.A., F.G.S., ...	197
Murray, S Allan	284

N

Nolan, Mr. M.R.I.A., ...	152
Norman and Tate, ...	84

P

Percy, on "Metallurgy,"	2, 157, 158
Petermann, Prof., ...	279, 282
Phillips, on "Metallurgy,"	2, 158
Praeger, R. Lloyd, B.A., B.E., M.R.I.A., ...	4, 161
Prestwich, Sir Joseph, F.R.S., ...	178
Prothero, Roland E., M.A., M.V.O., ...	281

R

Page
Ramsay, Prof., ... 94
Reade, T. Mellard, C.E., F.G.S., ... 9
Reid, Henry, C.E., ... 24, 110
Reynolds, Prof. J. Emerson, ... 184
Risler, M. 13, 33, 66, 70, 118
Rothamsted Papers, ... 14
Royal Agricultural Society, Journal of, ... 281
Royal Dublin Society, Publications of ... 120, 146
Royal Geological Society, Ireland, Journal of, ... 35, 228
Royal Irish Academy, Transactions of, ... 190
Royal Society, Philosophical Transactions of, ... 89

S

Scharff, R. F., B.Sc., Ph.D., ... 192, 193, 194, 196, 197
Schlich, Dr., ... 170, 171, 172
Schübler's Tables, ... 249, 250
Scott, R. H., F.R.S., ... 246, 254
Seeley, Prof., F.R.S., ... 249
Shaw, W. N., Sc.D., F.R.S., ... 276
Society of Psychical Research, Proceedings of, ... 182
Sollas, Prof., LL.D., F.R.S., ... 126, 146, 147, 161
Sowerby, Mr., ... 254
Stevenson, David, ... 164
Stewart and Corry, ... 155
Sullivan, Prof. K., ... 2
Symons, Mr. G. J., F.R.S., ... 263, 265

T

Teall, J. J. Harris, M.A., D.Sc., F.R.S., ... 127, 282
Templeton, S., ... 183
Thompson's "Study of Animal Life," 8
Tichborne, Prof., ... 184
Truchot, M., ... 118

W

Wade, Prof., ... 155
Warington, Prof., ... 250
Wakefield, on Irish Soils, ... 35
Watts, "Dictionary of Chemistry," 117
White, Gilbert, ... 8
Whitney, Dr. Milton, ... 280, 281, 288
Wilde, Sir Wm. R., ... 189
Wilkinson, Mr. John, ... 160
Wollny, ... 249, 250
Woodhead, Prof. S. A., ... 284
Wright, Mr., ... 192
Wright, Prof. R. Patrick, ... 284
Wright, W. B., B.A., ... 197
Wiley, Prof., ... 285, 287, 288
Wynne, Mr., ... 235

Y

Young, Arthur, ... 242

INDEX.

A.

Page
Acid Group of Rocks, . . 28
Acid Rocks, Table of Analyses of, ... 120
Aerial Currents, . . . 235
Afforestation, ... 169
Afforestation, Expenses and Profits, ... 170
Agherlow, Vale of, . . . 49
Agriculture, Influence of Irish Climate on, . . . 240
Agricultural Maps, . . . 33
Agricultural Maps—America, . 280
,, ,, Belgium, . 282
,, ,, France, . 279
,, ,, Germany, . 279

Alluvial Soils, Formation of, . 3
Alluvium, . . . 150, 164
Alteration due to Weathering, . 127
Aluminous beds, . . . 123
America, Agricultural Maps, . 280
American soils, Analyses of, . 288
Analyses, Mechanical, . . 287
Analyses of basic rocks, . 127
,, diorites, . . 126
,, limestone, . . 80
,, waters . . 128
Andesite, ... 30
Animal remains in Cave Deposits, 190
,, ,, Local Nomenclature, . 190
,, ,, in Peat, . 189
Anticyclonic Systems, Centres of, 257
Antrim South, Boulder-clay, . 205
Applications of Peat, . . 159
Aqueous Rocks, . . . 19
Area of Carboniferous Strata, . 80
,, of Red and of Upland Bogs, 152
Armagh and Down, Boulder-clay, 206
Artesian wells, . . . 181
Arterial drainage, . . . 168
Ash-constituents in Animals, . 91
Ashes, Composition of, . . 2
Aspect, Effect on Temperature, 247
Athlone bog, ... 3
Atmospheric moisture, . . 260
Auger, The, ... 286
Available Plant-food, . . 17

B.

Ballinahinch, Marble at, . . 58
Ballinskellig's Bay, Section of boulder-clay near, . . 236

Page
Ballintemple, Sand Waste, . 6
Ballycastle, Upper Basalt near, 123
Ballyconneely, coralline sands at 5
Ballyhalbert, erratic at, . . 131
Ballymena, Upper Basalt near, . 125
Banagher, eskers near, . . 224
Bantry Bay, coralline sand in, . 5
,, lower Drift at, . 36
,, Upper Boulder-clay, 144
"Bar Eskers," . . . 148
Barytes, ... 113
Barnavave Hill, . . . 51, 52
Basalt, ... 30
,, Analyses of, . . 128
,, of Antrim plateau, . 123
,, of Carboniferous Age, . 121
,, sheets, . . . 123
,, Soils after, . . 126
,, Upper, of Antrim, . 123
Basic Group of rocks, . . 30
,, rocks, . . . 121
,, ,, Analyses of, . 127
Bauxite, ... 112
Beauparc, Limestone at, . 47
Belfast, Water Supplies at, 176, 177
Belgium, Agricultural Maps, . 282
Black turf, ... 156
Bog-flows in Ireland, . 161-163
,, iron-ore, . . 112, 159
,, Area of, . . . 153
,, of Allen, . . . 151
,, Reclaimed, . . . 169
,, Springs in, . . . 160
,, Conservation of, . . 163
,, Rate of growth, . . 153
,, Red, ... 150
,, Submerged, . . . 5
Boulder-clay, . . 199, 201, 203, 205, 208, 215, 216, 218, 221, 226, 227
,, Lower, . .
,, ,, Leinster, District 4, 229
,, ,, in North Antrim, 204
,, ,, in South Antrim, 205
Boulder-clays, ...
,, S.E. of Londonderry, . . 201
,, Ulster, District 1, 199
,, ,, ,, 4, 208
,, Upper, . .141, 144
,, ,, at Bantry, 144

Page

Boulder-clays, Upper in North Antrim, 205
,, ,, in South Antrim, 205
Building stone, 22, 29
Bull's Head, 48
Burren District, 102

C.

Calcareous strata in Silurian Rocks, 66
Calp—earthy limestone, 88
Cambrian Rocks, 64
"Candle" or Gas Turf, 159
Carboniferous Sandstone and Shale, 81
Carboniferous limestone, 85
Carboniferous rocks in Cork, 84
Carboniferous strata, Area of, 80
Carboniferous strata, Deformation of, 85
Carboniferous strata, former extent of, 81
Carboniferous strata, Middle Series, 85
Carboniferous System, 80
,, ,, Upper Series, 102
Carlingford, Region of, 120
Causes affecting height of barometer, 266
Cave deposits, 190
Central Plain, 96
Chalk, 109
Chert in limestone, 87
Classification of clouds, 262
Clay, Composition of, 19
Clays, Analyses of, 21
Clays, Economic, Connaught District 1, 213
,, ,, 2, 215
,, ,, 3, 217
,, ,, 4, 219
,, Leinster District 1, 221
,, ,, 2, 225
,, ,, 3, 228
,, ,, 4, 331
,, Munster District 1, 333
,, ,, 2, 333
,, Ulster District 1, 201
,, ,, 2, 204
,, ,, 3, 208
,, ,, 4, 210
Clays, Economic uses of, 110
Clays, Lough Neagh, 110
Clay Soils, 7
Clifden, Marble at, 58
Climate and weather, 242
Climate, Effects of vegetation on, 241
Climate, Influence on Agriculture in Ireland, 240

Page

Climate, Influence on stock and tillage, 242
Climate, Seasonal modifications, 241
Clonakilty, Submerged bog near, 164
Clones, Drumlins near, 208
Clouds classified, 262
Coal, Formation of, 25
Coal Island, 110
,, Measures in Cork, 84
,, Scarcity of in Ireland, 80
Coals, Irish, 26
Comeragh, 69
Comeragh Mountains, Boulder-clay in valleys, 140
Composition of peat, Table of, 157
Compressed peat, 158
Condensation of vapour, 263
Configuration of Surface, 246
Connemara marble, 58
Conservation of bogs, 163
Contorted strata, 47
Copper, 111
Coralline sand, 5
Cornstones in Old Red Sandstone, 74, 77
Cork Harbour, Calcareous sand in, 5
Cor-Slieve, Moraine-formed lakes in, 149
Courses of Cyclones, 259
Cretaceous System, 109
Croaghan Hill, basalt of, 122
Croagh Patrick range, rocks of, 65
Crumpling of strata, 46
Crust (pristine), 50
Crystalline components of rocks, 26
Crystalline rocks, 27
Curragh Bogs, near Shannonbridge, 3
Cyclone Diagram, 257
,, Indications of, 255
Cyclones, Frequency of, 258
,, Table of numbers of, 258
,, Courses of, 259
Cyclonic Winds, 253

D.

Darvagh eskers, 204
Deformation of strata, 85
Deltas, 4
Denudation, 44
Denudation, marine, Plain of, 93
Denudation, River, 96
,, Sub-aërial, 94
Depression of land, 4
Deterioration of soils, 38
Devil's Bit, 69
Dew-point, 261
Dingle Beds, 48
Diorite, 126
Directions and rates of wind, 258
Disintegration of limestone, 10
,, mica-Schist, 56
,, rocks, 33
Distribution of erratics, 130

Page
Disturbance and crumpling of strata, 46
Dolerite, 30
Dolomite, Composition of, 25
,, Table of analysis of, 105
Doonera, Sand waste, 6
Drainage, Areas, 175
,, ,, Permeable Strata in 179
,, Arterial, 168
,, Areas of, 165
Drift 130
,, deposits, Springs in, 185
,, distribution, Ill-effect of, 143
,, material, Accumulation of, 93
Drifts around Omagh, 202
,, Connaught, 211
,, ,, District 1, 211
,, ,, District 2, 213
,, ,, District 3, 215
,, ,, District 4, 217
,, Leinster, 220
,, ,, District 1, 220
,, ,, District 2, 221
,, ,, District 3, 225
,, ,, District 4, 228
,, Munster, 232
,, ,, District 1, 232
,, ,, District 2, 233
,, ,, District 3, 336
,, north of Omagh, 202
,, north of Ox Mountains, 212
,, of Ireland, 198
,, S.E. of Londonderry, 201
,, Ulster, 198
,, ,, District 1, 199
,, ,, District 2, 201
,, ,, District 3, 204
,, ,, District 4, 208
"Drumlins," 138
,, near Clones and Castleblayney, 208
Dublin Water-supplies, 176
Dunlewy, Marble at, 58
Dunworly Bay, Peat below sea-level, 164
"Dykes," 125
,, of Igneous Rocks, 53

E.

Economic applications of peat, 156
Economic Clays, Connaught, District 1, 213
,, ,, District 2, 215
,, ,, District 3, 217
,, ,, District 4, 219
,, Leinster, District 1, 221
,, ,, District 2, 225
,, ,, District 3, 228
,, ,, District 4,
,, Munster, District 1, 233

Page
Economic Clays, Munster,
,, ,, District 2, 235
,, Ulster, District 1, 201
,, ,, District 2, 204
,, ,, District 3, 208
,, ,, District 4, 210
Economic minerals, 111, 128
Elements of enrichment, 37
Emlagh Bog, 156
Epi-diorite, 31
Erratics, Distribution of, 130
Errigal, Donegal, Basalt dykes, 126
Eskers, 146
Eskers, Connaught, District 1, 213
,, ,, District 2, 215
,, ,, District 3, 217
,, ,, District 4, 218
,, Leinster, District 1, 221
,, ,, District 2, 223, 224
,, ,, District 4, 230
,, Munster, District 2, 235
,, near Banagher, 224
,, ,, Tyrrellspass, 223
,, Ulster, District 2, 204
,, ,, District 3, 208
Evaporation, from trees, 277

F.

Falcarragh, Limestone at, 59
Feakle, Unconformability at, 48
Feed for young stock, 91
Felsite, 29
Felsitic Rocks, 118
Fern, fossil, 73
Fertile metamorphic areas, 56
Fire-clay, 103
Fir in peat, 154
Fixation of nitrogen, 17
Flats bordering Lough Erne, 151
Fodder, Mineral substances in, 92
Fore-shores, 4
Formation of subsoil, 10
Formations, Nature and order of, 42
Formations, Table of, 43
Formations traversed by Irish Rivers, 165-167
France, Agricultural Maps, 279
Frequency of cyclones 258
Fuel, Peat as, 157

G.

Gabbro, 51
Galtees, 69
Galtymore 49, 72
Geological Survey, The, 282
Germany, Agricultural maps in, 279
Giant's Causeway, 31
Glacial Drift, 35, 130

Page
Glacial Flood-gravels, 165
,, striæ, 134
Glaciation, General, 135
Gneiss, 28, 55
Gold, 111
Golden Vale, 35
Gort, Peat at, 154
Grange Con, Upper Drift at, 36
Granite, 28, 114
,, Age of, 114, 115
,, Analyses of, 128
,, Banding in, 116
,, Disintegration of, 116
,, Soils, 117
Granitic Soils, French, 117
Gravels, limestone, Leinster, District 2, 222
,, Munster, District 3, 239
Gulf Stream, 244
Gypsum, 23, 113

H.

Hardness of water, 186
Heating-power of peat, 157, 158
Hollows formed by solution, 98
Holywood, Dolomite at, 105
Hoos Field, Rothamsted, 16
Hornblende-schist, 31, 57
Humidity of atmosphere, Relative, 260
,, Relative, note on, 277
,, ,, Table of averages, 276
,, Table of, 261
Hunting-stock, feed for, 92

I.

Igneous rock, Dykes of, 53
Igneous rocks, 19
,, ,, Acid, 114
,, ,, Basic, 121
Inoculation of soils, 18
Irish Climate, Influence of, on Agriculture, 240
Irish coal-fields, 103
Irish coals, 26
Irish rivers, Formations traversed by, 165-167
Irish Sea soundings, 195
Iron, 111
Irrigation, 118, 128
,, Facilities for, 70
,, in Old Red Sandstone Areas, 78
,, on limestone land, 92

J.

Jurassic System, 108

K.

Page
Keeper Hill, 68
Kelp, Analyses of, 7
Kerry Head, Old Red Sandstone of, 74
Kilkelly, Upper Drift at, 144
Killary Harbour, 65
Killybegs, Rainfall at, 264
Killygordon, Limestone at, 59
Kilrea, Eskers in bog near, 208
Kinsale Harbour, Calcareous sands at, 5
Knock Boy, Coralline sand in, 5
Knocknashee, Section at, 45

L.

Laboratory work, 32
Latitude, Difference in temperature due to, 244
Lead, 111
Leading mineral nutrients, 15
Lias, 108
Life forms, mingling of southern and northern, 194
,, ,, Recent, 189
Lignite beds, 25
,, Formation of, 25
Limavady, Boulder-clay near, 203
Lime, 15
Lime-burning, 24
,, carbonate in Marls, Table of, 107
Limestone, 23, 58
,, Aggregate thickness of, 102
,, Analyses, 24
,, at Beauparc, 47
,, at Mitchelstown, 46
,, Detritus, 34
,, Disappearance northward, 83
,, disintegration, 10
,, gravels, Leinster, District 2, 222
,, solubility, 38
,, till near Clew Bay, 216
Londonderry, Drifts S.E. of, 201
Lough Erne, Flats bordering, 151
,, Basalt dyke near, 126
Lough Mask, Underground water-flow, 179
Lough Neagh, Upper Boulder-clay near, 207
Lower Basalt, 123
Lurgan, Chalk around, 109

M.

Magilligan, Sand tract at, 6
Magnesia in Agriculture, 13
Magnesian limestone, Analyses of, 105

Page
Mannin Bay, Coralline Sand at, 5
Manure Gravels, 34
Marble, 25, 58
Marine denudation, 44
Marl, described, 20
„ New Red, 107
„ So-called, 78
Marls, Analyses, 151
Mechanical analyses, 287
Mechanical analyses, Table of, 288
Metamorphic Rocks, 54
Metamorphism, 46
Meteorological records, 261
„ Tables, 269, 270
Meteorology, Applications of, 267
„ Concluding remarks on, 268
Mica-Schist, 55
Mica-Schist described, 20
Micro-organisms, 17
Migration, Conflicting opinions as to, 191
„ Opinions of Zoologists 192
„ Spontaneous, 191
Minerals, Economic, 111, 113
Minerals in Ireland, 128
Minerals, Table of, 27
Mineral Substances appropriated, 92
„ „ in fodder, 91
Mitchelstown, Limestone at, 46
Moher, Cliffs of, 44
Moraine Drift, Leinster District 3, 227
Moraines, 148
„ Munster, District 1, 233
„ „ District 3, 239
Mosses, Peat-forming, 155
Mud-deluges, 161
Mullagh, The, an Esker ridge, 204
Myroe, Sand tract at, 6

N.

Neagh, Lough, Alluvium, 4
Nenagh, Limestone detritus, south of, 140
„ Peat under boulder-clay near, 154
New Quay, Cornwall, recently-formed stone at, 6
Newtown Colliery, Remarkable sections in, 229
Newtownards, Erratic near, 131
Newtownlimavady, Raised beach near, 5

O.

Oak, found in Peat, 154
Obsidian, 30
Oldest land plants, 73
Old Red Sandstone areas, Irrigation on, 78
Page
Old Red Sandstone, " Cornstones " in, 72, 74
„ „ Divisions of, 71
„ „ Former extent of, 71
„ „ in Ulster and Munster, 74
„ „ mountains, 77
Omagh, Drifts around, and north of, 202
„ Formation of bog near, 153
Origin of upper clays, 144
Ox Mountains, Boulder-clay north of, 212

P.

Peat, 150
„ Animal remains in, 189
„ areas, reclamation of, 169
„ as fuel, 157
„ ashes, 2
„ Composition of, 157
„ Compressed, 158
Peat-filled hollows, 150
Peat-forming mosses, 155
Peat, heating power of, 158
„ Lignite, Coal, 25
Peat-litter, 159
Peat-mull, 159
Peat, Oak and Fir found in, 154
„ products, 159
„ Submerged, 164
Peat-wool, 159
Peaty lands, Trees for, 171
Permeable strata in Drainage areas, 179, 180
Permian Formation, 105
Phillipstown, Basalt at, 121
„ bogs, 3
Phosphates in limestone soils, 88
Phosphoric acid, 13
Physical features of Old Red Sandstone, 74
Physical features of Silurian ground, 68
Physical features of Carboniferous ground, 99
Pine Weevil, 172
Plain, Central, 96
„ of marine denudation, 93
Plane of mountain-tops, 94
Plants, Oldest, 73
Plutonic rocks, 27
Portrush, Submerged bog at, 164
„ Upper Basalt near, 125
Pristine crust, 50
Propagation, Submerged area of, 194
Pyrites, 112

Q.

Quartzite, 54, 59

Page

R.

Rainfall, 263
,, Regions of greatest, 265
,, ,, of least, 265
,, Table of 261
,, ,, Annual 264
,, ,, at Rothamsted 284
,, Tables of averages, 272, 273
Rain-gauges, 283
Rain-wash, 12
Raised beaches, 4
Rate of growth of bogs, 153
Reading, Sampling at, 285
Recent life-forms, 189
Reclamation of peat areas, 169
Red bogs, Area of, 152
Regions of greatest rainfall, 265
,, least ,, 265
Relative humidity, Note on, 277
,, ,, of the Atmosphere 260
Rhætic Beds, 108
River denudation, 96
Riversdale Bog, 3
Road-metal, 22, 29
Rock salt, 22, 113
Rocks and their lithological characters, 19
Rock solubility, 9
Rothamsted "Sampling Irons" 285
,, Soil Research, 282
,, Tables of Rainfall and Drainage, 284
Rutland, Sand-waste at, 6

S.

Sampling at Reading, 285
,, Rothamsted, 285
,, Woburn, 285
,, in America, 285
,, soils and subsoils, 285
Sands and gravels, 203
,, ,, Armagh and Down, 206
,, ,, Connaught, District 3, 217
,, ,, Leinster, District 1, 221
,, ,, Middle, 140
,, ,, Ulster, District 4, 210
Sand, sandstone and grit, 21, 22
Sands, Munster, District 2, 235
Sandstone and grit, 21
,, Flow of water in, 183
,, New Red, 107
,, ,, ,, Wells in, 182
Sand tracts, 6
Scawt Hill, Lower Basalt near, 123
Scenery of Metamorphic Rocks, 60, 61, 62
,, Old Red Sandstone, 75, 76
Scenic features of the Carboniferous Formation, 99

Page
Seaweed as manure, 7
Section across Galtymore, 49
,, across Slieve Bloom, 82
,, at Barnavave Hill, 52
,, at Knocknashee, 45
,, in part of Cork, 86
,, in South Galway, 72
Serpentine, 31, 58
,, at Croagh Patrick, 121
Shannon gorge, 98
Shannon river, Area of peat margining, 151
Shale described, 20
"Sheets," Basalt, 123
Shell gravels, 5
"Shoal-Eskers," 148
Shrinkage of peat, Table of, 157
Silurian areas, 64
,, hills, 69
,, limestone, 65
,, Rocks, calcareous strata in, 66
,, slate-rock, 68
Silver, 111
Slate, 113
,, described, 20
Slemish Hill, Lower Basalt near, 123
Slieve Bloom, Section across, 82
Slieve Croob granite, 114, 115
Slieve Donard granite, 115
Slieve League, Moraine-formed lake at, 149
Slieve-na-man, 69
Slob lands, 4
Soil, Formation of, 1
Soil-inoculation, 18
Soil replenishment, 9
,, research, Modern, 281
,, ,, Rothamsted, 282
,, ,, the British Isles 282
Soils after Basalt, 126
,, after Lower Carboniferous Strata, 83
,, ,, limestone, 88
,, ,, Silurian strata, 66
,, and subsoils, Sampling, 285
,, Discrimination of, 37
,, of Old Red Sandstone, 77
Solution, Hollows formed by, 98
Spontaneous migration, 191
Springs, in Drift deposits, 185
,, Rise and fall in, 184
Stations for Weekly Weather Reports, 270
,, ,, Table of Relative Humidity, 276
,, ,, Tables of Average Rainfall at, 272, 273
Stations for Weekly Tables of Average Temperatures at, 270, 271
,, ,, Tables of Hours of Bright Sunshine, 275
Steatite, 112
Stewartstown, Chalk near, 109

Page
Stock and tillage, Influence of climate on, . . . 242
,, feed for, . . . 91, 92
Stone-turf, . . . 156
Stratification, ... 42
Stratified Rocks, . . . 19
Submerged area of propagation, 194
Submerged peat, . . . 164
Subsoil, Formation of, . . 11
Sunshine, Table of average number of hours of, . . . 274
Superficial deposits, . . 33
Syenite, ... 30

T.

Table of Annual Rainfall, . . 264
Table of Analyses of Acid Rocks, 120
,, ,, Annalong and Kilkeel River Waters, . 177
,, ,, Ash Constituents in Animals, . 90
,, ,, Basalt and Granite, . 128
,, ,, basic rocks, . 127
,, ,, Belfast Water supplies, . 177
,, ,, black slate, 67
,, ,, clays and sandstones, 84
,, ,, clays, shales, and slates, . 21
,, ,, dolomite at Holywood, . 105
,, ,, dolomitic limestone, . 87
,, ,, Dublin Water, 176
,, ,, Grand Canal Water, . 177
,, ,, granite and basalt, . 128
,, ,, limestones, . 24, 89
,, ,, marls and clays, . 107
,, ,, metamorphic rocks, . 57
,, ,, peat, &c., . 153
,, ,, phosphatic limestones, . 88
,, ,, slates, . . 68
,, ,, waters at Lisdoonvarna and Lucan, 184
,, ,, waters at Ross's Factory, Belfast, 183
,, ,, showing hardness of waters, 128
,, Average Number of Hours of Bright Sunshine, . . . 274
,, Average Rainfall, 272
,, Averages of Relative Humidity, . . 275

Page
Table of Average Temperatures at Stations for Weekly Weather Reports, . . . 270
,, area of bog, . . 153
,, composition of peat, . 157
,, composition of earths of Vosges Sandstone, . . . 108
,, daily evaporation from certain trees, . 277
,, Daily Weather report, 269
,, drainage of various areas, . . . 168
,, differences in Temperature of soils, . 249
,, Formations, . . 43
,, ,, traversed by Irish rivers, 165, 167
,, frequency of cyclones, 258
,, heating-power of peat, 158
,, Hourly Weather report, . . . 276
,, Igneous Rocks, . 28
,, lime-carbonate in marls, . . . 107
,, Mean frequency of winds, . . 260
,, Mean Temperature, . 246
,, Mean Temperature of lowland peat-soil, . 251
,, Mean Temperature of upland peat-soil, . 251
,, Mean Temperatures of soil and air, . 250
,, mineral constituents in hydrosilicates, . 112
,, mineral resources in Limousin soils, . 118
,, minerals, . . . 27
,, mineral substances in fodder, &c., . . 92
,, Rainfall, . . . 255
,, ,, and Drainage at Rothamsted, . 284
,, Regions of greatest rainfall, . . . 265
,, soil and air temperatures, . . 252
,, Temperature, &c., . 261
,, showing differences of water and air temperatures, . . 245
,, Nature of Soils, Subsoils, and Boulder-clays, . 40, 41
,, shrinkage of peat, . 157
Tax upon soil-resources, . . 89
,, ,, soils, how met, . 91
Temperature, ... 243
,, Difference due to latitude, . . 244
,, Effect of aspect on, 247
,, Mean, of upland peat-soil, . . 251
,, Mean, of lowland peat-soil, . . 251

Page
Temperature, Mean, Table of, . 246
,, of Soil and Air, Table of, . . 252
,, water and air over the Atlantic, . 245
,, Table of, . . 261
,, Table of differences in soils, . . 249
Temperatures, Mean, of air and soil, . . 250
,, of air and soil, Relations of, . 249
,, Tables of Averages at Stations for Weekly Weather Reports, 270, 271
Tertiary Acid Rocks, . . 120
Tertiary Group, . . . 109
Three Rock Mountain, Megaceros heads in bog near, . . 189
Till, ... 139
Tillage, Influence of climate on, 242
Timber, Demand for, . . 170
Tin, ... 111
Toome deposits, . . . 4
Tramore, Peat sea-bottom, . 164
Transported soils, . . . 34
Trees for peaty lands, . . 171
Trias of the Continent, . . 107
Triassic System, . . . 105
Tyrrellspass, Eskers near, . . 223

U.

Underground waters, . . 179
Upland bogs, Area of, . . 152
Upper and Lower Drifts, . . 35
Upper Carboniferous Series, . 102

V.

Vapour, Condensation of, . . 263
Varec, Analyses of, . . . 7
Variability of wind-direction, . 253
Vegetation, Effects on climate, . 241
Volcanic rocks, . . . 27
,, vents, . . . 123

W.

Water, Analyses of at Ross's Factory, Belfast, . . . 183
Water, Dublin, Table of Analyses of, ... 176
Page
Water-finding, Specific case of, . 182
Water, Flow of, in sandstone, . 183
Water Hardness, . . 78, 186
Water of Annalong and Kilkeel rivers, Table of Analyses of, ... 177
Water-power, ... 187
,, Utilization of, . 187
Waters, Analyses of, . . 176
Watersheds, ... 175
Water Supplies, Allowance for contingencies, 178
,, ,, Belfast, Analyses of, . . 177
,, ,, Dublin, . . 176
,, ,, for towns, . 175
,, ,, quantity required, . 178
Weather, ... 242
,, Prognostication, . 266
,, Table of Daily Report, 269
,, Table of Hourly Report, ... 276
Wells in New Red Sandstone, . 182
Wet and dry winds, . . 262
Wexford Gravels, . . . 341
White turf, ... 156
Wind-direction, Variability of, . 253
Wind, Directions and rates of, . 258
Wind-drift, ... 12
Winds, Cyclonic, . . . 253
,, Mean frequency of, . 260
,, Wet and dry, . . 262
Woburn, Sampling at, . . 285
Worms, Function of, . . 8

Y.

Youghal Harbour, Calcareous Sands in, . . . 5
Young stock, Feed for, . . 91

Z.

Zeolites, ... 30
Zinc, ... 111

A. T. & Co. (Ltd.).
1000. P. 509. 2. 07. (1. 06).—11838

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

QE
265
K5

Kilroe, James Robinson
A description of the soil-geology of Ireland

P&ASci.